TOPICS SUITABLE FOR DEVELOPING PRINCIPLES OF PHYSICAL SCIENCE IN A COURSE IN PHYSICS FOR THE SENIOR HIGH SCHOOL

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Thesis

TOPICS SUITABLE FOR DEVELOPING UNDERSTANDINGS OF PRINCIPLES OF PHYSICAL SCIENCE IN A COURSE IN PHYSICS FOR THE SENIOR HIGH SCHOOL

by

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CHAPTER I

SURVEY OF RELATED LITERATURE

Introduction

In his search for truth the scientist has evolved a mode of attack known as the scientific method. It almost always involves the same steps whether he is interested in mountains or microbes, synthetic rubber or the force of gravity.

The true scientific method, as we recognize it, was not fully developed until the beginning of the seventeenth century when Galileo applied the experimental method. It has been steadily gaining adherents among leaders in all the fields of education, although this method must have first consideration in the teaching of science.

There have been few points in educational discussions on which there has been greater agreement than that of the desirability of teaching the scientific method. The first step in the scientific method is: locating and defining the problem.[1] Its application

[1] Science Education in American Schools, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I. Chicago; University of Chicago Press, 1947. p. 167.

is a matter of securing the correct explanation, or, if that is not definitely known, of finding the best explanation. The elements of the scientific method should lead to action in life and to scientific appreciations and attitudes, and should contribute to intelligent planning.

The scientific method is now becoming recognized as a definite, tried, and tested procedure in problem-solving. As soon as effective means of teaching the elements of scientific method and the scientific attitudes are found, the chances of success of high school students in meeting and solving everyday problems will be greatly enhanced.

For the past fifteen years there have been vast surveys and much research done in an attempt to bring about an accepted standard for all forms of instruction. This is particularly true in the field of science education. At this point, a number of important surveys will be listed to show clearly that there is a need for the adoption of principles of science as objectives of science instruction.

The status of science teaching is difficult to determine. A pertinent study, "Instruction in Science," was made in 1932 by Wilbur L. Beauchamp,[2] who analyzed

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[2]Wilbur L. Beauchamp, Instruction in Science, U. S. Office of Education, Bulletin, 1932, No. 17, National Survey of Secondary Education, Monograph No. 22. Washington: Government Printing Office, 1933.

58 courses in general science, 45 courses in biology, 27 courses in physics, and 30 courses in chemistry, all of which had been revised since 1925. The purpose of this investigation was to evaluate the objectives of science teaching. The analysis showed that there is at the present time no conclusive method for determining and evaluating the objectives of science teaching, but did, however, disclose the trends which should be given careful consideration by those who are trying to improve instruction in secondary school science.

In the field of science, two significant reports of national societies set forth aims of education. In view of these aims, the committees responsible for the two reports made specific recommendations concerning an organization for courses in science that would contribute to aims of general education. According to the Thirty-First Yearbook[3] Committee, which was the first educational group to advocate the teaching of principles as objectives of science teaching, classroom experiences must be provided in the classroom to satisfy one of the general aims of education, namely, "Life Enrichment through Participation in a Democratic Social Order. The education of an individual is the effect on

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[3] A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Illinois: Public School Publishing Company, 1932. p. 42.

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[3] A Program for Teaching Science, Thirty-First Yearbook of the National Society for the Study of Education, Part I, Bloomington, Illinois: Public School Publishing Company, 1932. p. 42.

his whole behavior that has come from the experiences in which he has participated. A planned program of education (the ambition of educational workers) is one that provides experiences that will contribute as fully as may be to the attainment of life enrichment."[4]

In 1938 the Thayer Commission of the Progressive Education Association, which, along with the Thirty-First Yearbook Committee, has had a marked influence on the reorganization of science teaching in American schools, states, "The purpose of general education is to meet the needs of individuals in the basic aspects of living in such a way as to promote the fullest possible realization of personal potentialities and the most effective participation in a democratic society."[5]

The Thirty-First Yearbook, together with the report of the Thayer Commission, which also recommended the reorganization of courses in science around generalizations, gave added impetus to an interest in principles of science as an objective of science teaching in all grades.

The Thirty-First Yearbook committee proposes, "that the curriculum in science for a program of general education be organized about large objectives,

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[4]Ibid.

[5]Progressive Education Association, Commission on Secondary School Curriculum, Science in General Education, p. 23. New York: D. Appleton-Century Company, 1938.

that understanding and enlargement of these objectives shall constitute the contribution of science teaching to the ultimate aim of education, and that the course of study be so organized that each succeeding grade level shall present an increasingly enlarged and increasingly mature development of the objectives."[6]

The Committee in clarifying its point of view regarding the form the large objectives shall take says, "The objectives may be stated as the principles and generalizations that are functional for the individual, in that they enable him to interpret the experiences of living."[7] In concluding its recommendation concerning the organization of instruction in science the Committee recognizes, "the aims of science teaching to be contributory to the aim of education; viz., life enrichment. It recognizes the objectives of science teaching to be the functional understanding of the major generalization of science and the development of associated scientific attitudes."[8]

By generalization or principles the committee means, "the abstractions formed from the connections of related situations and responses."[9] The committee says

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[6] A Program for Teaching Science, op. cit., p. 44.

[7] Ibid., p. 43.

[8] Ibid., p. 57.

[9] Ibid., p. 42.

further that "A functional understanding of a principle has been attained if the learner has acquired ability to associate with the principle the ideas from his immediate and from his subsequent experiences that are related to it and if he is able to apply the principles in practical situations."[10]

Downing[11] maintains that an understanding of the important principles of health, scientifically cultivated in their lives, must be developed to lead pupils into healthful ways of living. Again, pupils must first understand the principles of heredity, of home sanitation, and be able to apply them to specific situations if they are to become worthy members of the home.

SURVEY OF IMPORTANT RESEARCH STUDIES PERTAINING TO THE DETERMINATION OF PRINCIPLES AS OBJECTIVES OF SCIENCE TEACHING

According to Martin,[12] there are three independent centers of research at which the work toward the clarification of the concept of a scientific principle and toward the refinement of principles has chiefly been carried out, namely:

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[10] Ibid., p. 43.

[11] Elliot Rowland Downing, An Introduction to the Teaching of Science, p. 6. Chicago: University of Chicago Press, 1934.

[12] W. Edgar Martin, "A Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science, Science Education, XXIX (February, 1945), p. 45.

(1) The University of Chicago, where the research was under the direction of Elliot R. Downing.
(2) Columbia University, where the research was under the direction of S. Ralph Powers and Gerald S. Craig and,
(3) The University of Michigan, where the research was under the direction of Francis D. Curtis.

The Fifth Yearbook of the Department of Superintendence of the National Education Association[13] states that in order for our knowledge of science to be of the largest service, it must be in the form of principles. The design of a course in science should enable the pupils to have experiences with the attainment of knowledge of those principles that are socially useful, and should provide much drill in applying them to life situations.

In the past two decades this problem has gained wide recognition, and as a result there has been increased interest focused on the importance of principles as objectives in science instruction. One of Downing's[14] early studies, in 1925, formulated the following three steps for the solving of a scientific problem, involving the use of generalization, or principle: (1) accumulation of facts; (2) discovery of the relation and

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[13] The Junior High School Curriculum, Fifth Yearbook, Department of Superintendence, National Education Association, p. 150. Washington: Government Printing Office, 1927.

[14] Elliot R. Downing, Teaching Science in the Schools, p. 53. Chicago: University of Chicago Press, 1925.

sequence of such facts reduced to generalizations; and (3) discovery of the approximate causes that underlie such laws or principles.

Craig,[15] in planning a course of study in science for the elementary grades, states that the elementary school should not be concerned so much with training boys and girls to become scientists, but with helping them to become intelligent laymen. To accomplish this purpose, a course of study should be instigated that will develop certain objectives that agree with the facts, principles, generalizations, and hypotheses of science that are essential in the understanding of natural phenomena which challenge and intrigue children.

Unfortunately the textbooks in most of the high-schools do not devote a very large amount of their space to an elucidation of principles or to the application of principles to problematic situations.

In 1928 the position of principles in general science textbooks was one of minor importance according to the findings of the study made by Heinemann[16] who in the

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[15]Gerald S. Craig, Certain Techniques Used in Developing a Course of Study in Science for the Horace Mann Elementary School, Teachers College Contribution to Education, No. 276, pp. 12-13. New York: Teachers College, Columbia University, 1927.

[16]Ailsie M. Heinemann, "A Study of General Science Textbooks," General Science Quarterly, XIII (November, 1928), 11-23.

analysis of twenty such books found only ninety-three principles. They were given little spatial importance, only a little more than twelve percent of all reading space. Heinemann recommended placing the teaching emphasis on a small number of principles with multiple applications rather than on a large number of principles with few applications. As a criterion for a principle Heinemann defines a principle of science as a "statement of relationship frequently causal in nature between two facts."[17] Significant conclusions of the investigator were that principles were not uppermost in the minds of the authors when the books were written and that there was little unanimity among authors as to which scientific principles are of greatest importance at the general-science levels in the schools.

Hackett[18] made a similar analysis of twelve textbooks in biology. He found the amount of space devoted to the discussion of biological principles and their applications to problematic situations ranged from 48 to 23 per cent of the total word space of the books. The larger part of the book was in each case descriptive and factual. In both of these analyses the word-space devoted to such facts or descriptions that served to

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[17] Ibid., p. 11.

[18] H. L. Hackett, "An Analysis of High School Textbooks in Biology in Terms of Principles," Master's Thesis, University of Chicago, School of Education, 1925.

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[17]Ibid., p. 11.

[18]H. L. Hackett, "An Analysis of High School Textbooks in Biology in Terms of Principles." Master's Thesis, University of Chicago, School of Education, 1928.

lead up to the understanding of a principle or to illustrate the principle was counted a part of the material belonging to a discussion of principles.

A study by Peter Koppenaal[19] in which an analysis was made of a dozen of the more recent textbooks in physics for high school use shows that the average amount of space devoted to a discussion of principles and of problematic situations demanding their application is about 28 per cent of the total word space of the book. The extremes are 17.6 and 42.3 per cent. Some sixty principles are presented by these textbooks. The largest number discussed in any one text is forty-three.

A similar analysis of current chemistry texts for secondary schools has been made by Loren T. Lucas.[20] He states that the average space devoted to principles and problems involving their application is also slightly less than thirty per cent.

In contrast with these figures for science texts at the high-school level, Menzies[21] finds that the

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[19]Peter Koppenaal, "An Analysis of High School Physics Textbooks in Terms of Principles. Master's thesis, submitted to the University of Chicago, Department of Education, 1932.

[20]Loren T. Lucas, "Analysis of Chemistry Texts in Terms of Principles." Master's thesis, University of Chicago, Department of Education, 1932.

[21]Jessis A. Menzies, "An Analysis of Ten General Biologies of College Level in Terms of Generalizations and Their Application to Life Situations." Master's Thesis University of Chicago, School of Education, 1927.

smallest amount of space devoted to principles and applications in a dozen college biologies which she analyzed is 87 per cent and the maximum 97.6 per cent. In these books comparatively little attention is paid to the application of the principles to problematic situations.

Fourteen textbooks of general science used in the ninth grade were analyzed by Oliver B. Wilbur[22] in 1931. The criteria of a principle were formulated in a Seminar in Problems in the Teaching of Science, University of Michigan. The definition of a principle and the criteria for the selection of principles that were used by Wilbur are listed by Martin.[23] These principles were tabulated and submitted to subject-matter specialists in biology, chemistry, geology, and physics for validation in terms of the criteria and for revision of inaccurate and unsatisfactory statements. The list of 170 principles was then given to ten teachers of science who were asked to designate them as necessary, desirable, or undesirable in a general science course. It was found that from all fourteen textbooks only eighteen of the 170 principles were given, even in part,

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[22]Oliver B. Wilbur, A Study of the Principles of Science contained in General Science Textbooks Published Since the Beginning of the Year 1924. Unpublished Master's thesis, University of Michigan, 1931.

[23]W. Edgar Martin, "A Chronological Survey of Research Studies on Principles as Objectives of Instruction in Science," Science Education, XXIX (February, 1945), p. 46.

in principle form, in more than half of the textbooks analyzed. Five of these eighteen principles were regarded as necessary by ten of the instructors who evaluated them.[24]

A group of studies was made at the University of Chicago to show that it is desirable to learn by objective studies what principles of science are most often needed in solving the problems encountered in life by the average person and the order of their importance. Downing[25] compiled a list of ninety-six necessary principles in chemistry, physics, and biology determined by these studies in the order of their importance.

In 1934 Robertson[26] made an investigation, under the direction of Curtis, to determine the important principles of science suitable to serve as goals of instruction in the elementary grades. Ten previously completed studies were used as sources for the development of a comprehensive list of major and minor principles of science. A final list of 243 principles was evolved and submitted to twenty experts in the field

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[24]Wilbur, op. cit., p. 47.

[25]Downing, op. cit., pp. 39-48.

[26]Martin L. Robertson, "The Selection of Science Principles Suitable as Goals of Instruction in the Elementary School." Science Education, XIX (February, 1935), 1-4; XIX (April, 1935), 65-70.

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of science for evaluation as to the suitability of each principle for inclusion as one of the ultimate goals of instruction in elementary science. This list was finally reduced to 113 as a result of the evaluation.

Pruitt[27] made a study in 1935 in the field of chemistry to determine the concepts and generalizations which are of most distinctive value to man in interpreting his environment. During this study he analyzed three college-entrance examinations; one year's issues of the Atlantic Monthly, The Forum, and Harper's magazine; slightly more than 50,000 pages of material in five books of sociology; one year's issues of eight newspapers; 12 issues each of Popular Science Monthly, Scientific American, and Science News Letter; and also sixty-five textbooks in various fields in science. By using the same criteria for a principle as were used previously by Robertson, a list of 135 chemical concepts and generalizations was formulated with the principles arranged in an approximate order of their importance.

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[27] Clarence Martin Pruitt, An Analysis, Evaluation, and Synthesis of Subject-Matter Concepts and Generalizations in Chemistry. Doctor's dissertation, Teachers College, Columbia University, 1935. Distributed through Science Education. See Third Digest of Investigations in the Teaching of Science by Francis D. Curtis. Philadelphia: P. Blakiston's Son and Company, Inc., 1939, pp. 153-163.

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In 1941 Wise,[28] made a study to determine what principles of physical science are most important for general education. The procedure involved the following four problems: (1) the development of a tentative list of principles of physical science; (2) the determination of the relative importance of principles as measured by the scope of their applicability in the solution of frequently encountered problems; (3) the evaluation of the results obtained in contributing studies; and (4) a synthesis of evaluations on the basis of the judgment of experts.

In his investigation of the principles of the physical sciences Wise[29] used the following criteria for a principle:

A. To be a principle a statement must be a comprehensive generalization describing some fundamental process, constant mode of behavior, or property relating to natural phenomena.
B. It must be true without exception within limitations specifically stated.
C. It must be capable of illustration.
D. It must not be a definition.

These criteria were very similar to those employed by Robertson, Arnold, and Pruitt. A complete

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[28]Harold E. Wise, A Determination of the Relative Importance of Principles of Physical Science for General Education. Unpublished Doctor's dissertation, University of Michigan, 1941. See Science Education, XXV (December, 1941), 371-9; XXVI (January, 1942), 8-12; XXVII (February, 1943), 36-40; XXVII (September-October, 1943), 67-76.

[29]*Ibid.*, p. 371.

list of principles of chemistry, physics (including astronomy and meteorology), and geology was compiled from the lists of principles developed by Arnold, Hartman and Stephens, Pruitt, and Robertson. Then, whenever three or more judges questioned the assignment of an application to a principle, these duplications were discarded from the composite list.

If two or more applications appearing under any one principle were considered to be duplicates by the judges, the investigator retained under the principle those applications which were most clearly stated. These principles resulting from the application of the criteria were classified into the following fields: Physics, 165; chemistry, 68; and geology, 19.

This list of principles was then submitted to three subject-matter specialists for an evaluation of each principle against the investigator's criteria, and also in regards to the adequacy of the manner of statement of each principle. Written recommendations were submitted by the specialists to the investigator for the restatement of certain principles "in accordance with the criterion pertaining to the accuracy of the statement."

This list of 252 principles contained a final

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[30]Ibid., p. 373.

list of 191 principles of the physical sciences, each of which was further evaluated on the basis of its applicability to the interpretation of problematic situations commonly encountered in general living. Eleven textbooks were analyzed for applications to related principles. 3,403 applications were secured as a basis in courses of physical science.

Twenty additional principles were added to the tentative list of 252 principles as a result of the appearance of applications which could not be assigned to those principles already formulated. The final defensible list of 272 principles of the physical sciences were arranged by Wise so that 264 principles were in the relative order of importance for general education grades I-XIV, inclusive.

In 1945 Martin[31] reported a chronological survey of research studies of principles as objectives of instruction in science. In this survey, he gives a description of 18 studies of principles of science. Included in these 18 studies, however, are 11 contributing studies, making a total of 29. Martin's study of the principles of the biological sciences of importance for general education brings the total to 30 research studies of principles of science as objectives of instruction in science.

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[31]Martin, op. cit., 45-52.

Martin's[32] study closely paralleled that of Wise. His study was divided into two phases: (1) the inductive phase, the purpose of which was to secure a tentative list of the important principles of the biological sciences; and (2) the deductive phase, the purpose of which was to determine those principles in the "master" list which are of importance as objectives of instruction in science in a program of general education.

In his investigation Martin used the following criteria[33] for a principle:

> (1) It must be a comprehensive generalization which resumes the widest possible range of facts within the domain of facts with which it is directly concerned. The facts resumed in the generalization must denote:
> a. Objects and/or events and the relation between them.
> b. Properties.
>
> (2) It must be scientifically true. To satisfy a criterion:
> a. It must be verifiable; i.e. it must be stated so that it suggests, directly or indirectly, a definite operation of observations or experiments whereby its truth value can be tested or verified.
> b. It must be consistent with the body of accepted scientific knowledge, and except for a few limiting or singular exceptions, with all the data (facts) relevant to it.

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[32] W. Edgar Martin, "A Determination of the Principles of the Biological Sciences of Importance for General Education," Science Education, XXIX (March, 1945), 100-105; XXIX (April-May, 1945), 152-163.

[33] Ibid., p. 101.

A list of important biological generalizations resulted from an analysis of three biology textbooks used in junior colleges, three textbooks of high-school biology, a survey series of biological science for the general reader, and reports of five research studies. The statements against two criteria of a principle were checked by three science educators, and these statements were refined by three biologists. Then a "master" list was organized consisting of 300 major and 236 minor principles.

Sylvia Fleish[34] made a survey based upon the scientific interest of pupils in grades VII through XII in four communities of Massachusetts to determine those science principles which should become the knowledge objectives of the general-science course. A list of sixty principles was based upon numerous questions submitted by pupils. Ten general-science textbooks were next examined to determine whether they gave space to the sixty principles found underlying the science questions asked by the students. The survey showed that although many of the textbooks did include most of the listed principles, these generalizations were not stated in clear or concise language.

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[34] Sylvia Fleish, The Formulation of the Science Principles That Should Become the Objectives of General Science Teaching in the Junior High School. Unpublished Master's thesis, Boston University, 1945.

In 1946, Jones[35] made an investigation to determine the principles of science found in seven ninth-grade textbooks of general science. 146 principles were found to satisfy the following criteria used by Jones:

> A principle is a comprehensive generalization which
>
> Is stated positively and definitely.
> Is true but with rare exceptions within the limitations set up by the statement.
> Clearly states or implies a dynamic process or interaction.
> Is demonstrable experimentally.
> Is not merely a definition or a description.
> Does not deal with specific substances or varieties.
> Has meaning outside of the context.

Jones concluded that there is little or no agreement as to the number and selection of scientific principles included in the seven text-books of general science.

Bergman[36] conducted a study to determine the principles of entomology that are of significance in general education. His study consisted of an analysis of ten general entomological and seven popular entomological textbooks, thirty reference books dealing with

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[35]Ruth V. Jones, A Study of the Principles of Science Found in Ninth-Grade Textbooks of General Science, Unpublished Master's thesis, University of Michigan, 1946.

[36]George J. Bergman, "A Determination of the Principles of Entomology of Significance in General Education," <u>Science Education</u>, XXI (February, 1947), 23-32; XXXI (April, 1947), 144-157.

specific aspects of entomology, and a total of 140 research bulletins, journals, professional biological periodicals, and miscellaneous publications. Careful examination of these resulted in a total of 52 entomological principles.

This list of 52 entomological principles was checked against principles of biology to determine whether they were actually based upon, related to, or subordinate to them by comparing these principles with studies made by Martin, Downing, and Winokur. A list of the principles of entomology in the order of their relative importance in general education was formulated. It was concluded that this list of principles of entomology is subordinate to, is related to, or corresponds to a total of 45 (27 major and 18 minor) principles of biology.

Keeslar[37] made an investigation to determine to what extent certain selected instructional films in science contribute to the realization of three of the major objectives of education. He selected twenty-four of the best instructional films in science for his study and found that, even though they are fitted to teach scientific principles, elements of the scientific method, and scientific attitudes, yet they reveal no

[37]Oreon Keeslar, "Contributions of Instructional Films to the Teaching of High School Science," <u>Science Education</u>, XXX (March, 1946), 82-88; XXX (April, 1946), 132-136.

definite attempt to do so. The author reports that almost half of the contents of these selected films make no contribution to the three major objectives.[38]

The Committee on Science of the National Society for the Study of Education in its Forty-Sixth Yearbook[39] used criteria to state the objectives for science. In accordance with this list of criteria, the Committee proposed eight types of objectives for science instruction. The functional understanding of principles was one of the major types representing a learning outcome.

Leonelli[40] made an analysis of eight eighth-grade textbooks of general science. His investigation revealed a total of one hundred and eighty-six different principles. Of this total one hundred and forty-four principles were physical science principles and the remainder, forty-two principles, were biological science principles.

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[38] Ibid., p. 82.

[39] Science Education in American Schools, Forty-Sixth Yearbook of the National Society for the Study of Education, Part I. Chicago; University of Chicago Press, 1947. p. 25.

[40] Renato E. Leonelli, Principles of Physical and Biological Science Found in Eight Textbooks of General Science for Grade Eight. Unpublished Master's thesis, Boston University, 1947.

SURVEY OF LITERATURE PERTAINING TO THE DETERMINATION OF THE EFFECTIVENESS OF PRINCIPLES IN TERMS OF RETENTION OF LEARNING

Tyler,[41] in a study at Ohio University for the comparison of the results of course examinations in zoology, finds that specific facts were most quickly forgotten, but that information of more general application is more permanent, and that during a 15-month period, students do not lose the ability to apply zoological principles to new situations. He concludes that colleges should develop their examinations to center around objectives which have more permanent value in college education.

Frutchey[42] gave five pre-tests measuring certain knowledge, skills, and abilities to students studying chemistry in three Ohio high schools. Gains were measured by a test given nine months after the pre-tests, and retention was measured one-year after completion of the course. It was found that, in the application of principles, both boys and girls retained the same percentages of their progress made in the course. Thus principles are retained longer than facts, and are therefore more valuable in an educational program.

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[41] Ralph W. Tyler, "Permanence of Learning," Journal of Higher Education, IV (April, 1933), 203-204.

[42] F. P. Frutchey, "Retention in High School Chemistry," Educational Research Bulletin, Ohio State University, XVI (February, 1937), 34-37.

Johnson's[43] survey on the extent of retention of botanical information reports that those students who had have the most botanical information at the time of completing the course are very likely to retain the most after intervals of 15 and 27 months. He also finds that the rate of loss is quite rapid in the ability to retain botanical information during the three and fifteen months after completing the course. But this was later followed by a gradual decline.

Zeigler[44] shows that students apparently retain only those principles which they meet in every-day life-situations. He concludes that, although much of the science knowledge is practical and useful, too much emphasis is placed on facts which will not later be retained.

In a study on the retention of course growth, Wert[45] finds that retention is greater with less specific information, and that, with the passage of time, there is some gain in the ability of students to apply principles of zoology to new situations.

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[43] Palmer O. Johnson, "The Permanence of Learning in Elementary Botany," The Journal of Educational Psychology, XXI (January, 1930), 37-47.

[44] Robert T. Zeigler, "A Study of Fact Retention in General Science," Science Education, XXVI (February, 1942), 83-84.

[45] James E. Wert, "Twin Examination Assumptions," Journal of Higher Education, VIII (March, 1937), 136-140.

Reek[46] shows, in an investigation on this survey of studies made by Johnson, Wert, Tyler, Frutchey and others, that it is important to teach science principles in terms of retention of learning, and that it is highly unsatisfactory to teach unrelated facts in terms of retention.

SURVEY OF LITERATURE PERTAINING TO THE DETERMINATION OF SUBJECT-MATTER TOPICS TO BE USED FOR DEVELOPING PRINCIPLES OF SCIENCE

In the assignment of subject-matter topics to principles, Blanchet[47] used Martin's list of 300 principles of the biological sciences and Wise's list of 272 principles of the physical sciences. Using the criteria of a principle that these two men employed, Blanchet's investigation consists of four parts. In each, the physical sciences and the biological sciences are treated separately:

(1) A determination of the principles of science most suitable as goals for survey courses in the natural sciences at the junior-college level.

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[46] Doris Lucille Reek, A Study of the Principles of Science Found in Four Series of Textbooks of Elementary Science. Unpublished Master's thesis, University of Michigan, 1943.

[47] Waldo Emerson Blanchet, A Basis for the Selection of Course Content for Survey Courses in the Natural Sciences. Unpublished Doctor's dissertation, University of Michigan, 1946.

(2) A determination of the extent to which these principles are included in textbooks published for use in survey courses in the natural sciences.
(3) A determination of the subject-matter topics found in textbooks for use in the natural sciences, as a source of informational materials with which to develop understandings of these principles.
(4) A determination of student opinion concerning the relative values of topics which they had studied in survey courses in the natural sciences.[48]

In the first part of his investigation Blanchet determined, on the basis of the combined judgments of college teachers of science and of specialists in the teaching of sciences, the principles of science most suitable as goals for survey courses in the natural sciences.[49]

In order "to determine the extent to which the principles of science most suitable as goals for survey courses in the natural sciences were included in textbooks published for use in these courses,"[50] Blanchet developed criteria for selecting principles from the textbooks. This was necessary because a trial examination of several of the textbooks revealed that there were variations in the manner in which principles were stated. A statement was considered to be that of a particular principle:

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[48]Ibid., p. 35.

[49]Ibid., p. 38.

[50]Ibid., p. 115.

(1) If it expressed completely the idea in the original statement of the principle.
(2) If, though it did not state all of the elements of the principle, it was referred to by the author or authors as being the said principle.
(3) If it unmistakably implied the principle and could be reworded so that the principle was stated.
(4) If, though it did not state the principle in full, it could be combined justifiably with another statement in the same paragraph or section, which together stated the principle or could be reworded to do so.

Blanchet then formulated a composite outline of topics related to the physical sciences and another outline related to the biological sciences. When all of the topics related to each separate outline had been combined, the composite outline was re-examined and checked by the investigator. Three copies were made and submitted to three specialists in the teaching of science, who examined the outline critically to insure that the position of each topic in the outline was defensible, and secondly, that no topic, although worded differently, appeared more than once in the outline. The final step involved the determination of the frequency of appearance of the topics contained in the two composite outlines.

The last part of Blanchet's investigation was "to allocate a selected sampling of the topics of the two composite outlines under the principles of science that were important as goals of instruction in survey courses

in the natural sciences."[51] A copy of the list of principles of the physical sciences and the biological sciences with their assigned topics was submitted to each of three specialists in the teaching of science in order to check the defensibility of assignment of these topics to the various principles. "A total of 1171 assignments of physical topics was made to the (272) physical principles and 970 assignments of biological topics were made to the 300 principles of the biological sciences."[52]

Blanchet stated as a conclusion that, even though there was a diversity in the contents of the textbooks investigated, yet they did include suitable materials for developing understandings of principles.

SUMMARY OF RESEARCH STUDIES

The report of the Thirty-First Yearbook committee and the Thayer Commission recommend that courses in science can best contribute to the aims of science education when organized around principles of science. Subsequent studies justifying this recommendation were undertaken at the University of Chicago, under Downing; University of Michigan, under Curtis; Columbia University, under Powers and Craig; New York University, un-

[51] *Ibid.*, p. 302.

[52] *Ibid.*, p. 307.

der Peiper and Robertson; and also at Boston University, under Miles.

The studies by Wise and Martin brought together in two separate lists principles of the physical sciences and the biological sciences of importance of general education for grades I through XIV. However, these two investigators did not attempt to determine principles suitable for any particular grade level.

The studies made by Johnson, Tyler, Frutchey, Wert, and Zeigler indicate that principles, when learned, become a part of a pupil's mental equipment, but facts merely memorized are soon forgotten.

According to Fleish and Jones our leading textbooks of general science do not agree as to the number, selection and spatial importance of principles.

It would seem that we can accept the point of view that the broad generalizations of science have much guidance value and that they are an important element in curriculum construction. The majority of studies of principles of science have been limited to the secondary level. Only a few have dealt specifically with principles of science for courses in science at the college level. These have dealt, for the most part, with methods of teaching.

THE PROBLEM OF THIS INVESTIGATION

This investigation involves the subject-matter content of five high-school textbooks of physics. It is proposed to prepare a composite topical outline of the five books and to assign the resultant major topics to principles of physical science developed by Wise, on the basis that a discussion of the subject-matter found in the topical outline under the major topics might be reasonably expected to lead to a development of an understanding of the principles to which they are assigned. This investigation has the potentiality of use as a guide in the selection of subject matter topics suitable for inclusion in a high-school textbook of physics, and also, to assist instructors in their choice of subject-matter designed to develop a particular major generalization, or all the principles.

STATEMENT OF THE PROBLEM

The purpose of this investigation is (1) to prepare a composite topical outline of the subject-matter topics found in five high-school textbooks of physics, as a source of informational materials with which to develop understandings of principles of physical science, and (2) to assign to principles of physical science those topics which a study of might reasonably be expected to contribute to the development of an understanding of the principles.

SCOPE AND LIMITATIONS OF THE INVESTIGATION

The study is limited to a solution of the problem as stated. It is limited to the use of five high-school textbooks of physics in the preparation of the topical outline, and the use of the list of 272 principles of physical science developed by Wise.

No attempt is made to determine the frequency of a principle in any one textbook; to arrange the items in the topical outline in the order of their importance or in the best order for teaching; or to arrange topics under the principles to which they contribute in the order of their relative values in contributing to an understanding of the principles.

CHAPTER II

DEVELOPMENT OF A COMPOSITE TOPICAL OUTLINE

STATEMENT OF THE PROBLEM

The purpose of this part of the investigation is to prepare a composite topical outline of the subject-matter topics found in five high-school textbooks of physics, as a source of informational materials with which to develop understandings of principles of physical science.

SELECTION OF THE TEXTBOOKS FOR ANALYSIS

For the purpose of this investigation the following criteria for the selection of textbooks for subject-matter topics were that the textbook must:

(1) Be available for use at the time the study is started;
(2) Have been published by a well-known publishing house;
(3) Have been published or revised since 1935; and
(4) Be representative of the textbooks of physics used in high schools.

The following five textbooks of physics which met these criteria, were used in this investigation:

<u>Dynamic Physics</u>, Bower, Ernest O., and Robinson, George H. New York: Rand McNally and Company, 1942.

<u>Modern Physics</u>, Dull, Charles E. New York: Henry Holt and Company, 1945.

Physics of Today, Clark, John A., Gorton, Frederick R., and Sears, Francis W. Boston: Houghton Mifflin Company, 1943.

Physics, Whitman, Walter G., and Peck, A. P. Boston: American Book Company, 1946.

Elementary Practical Physics, Black, Newton H., and Davis, Harvey N. New York: Macmillan Company, 1946.

TECHNIQUES EMPLOYED

The first step was the formulation of a composite outline of topics from the five high-school textbooks of physics. The subject-matter topics contained in a textbook were considered to be its chapter, center, and paragraph headings. For each textbook an outline form was made in accordance with the way the author or authors arranged them in the respective texts.

Upon inspection of these outlines, the following major divisions of physics included in the textbooks became apparent: mechanics, heat, sound, light, magnetism and electricity, and modern physics.

It was planned to use the outline of the one textbook by inspection which seemed to have the largest number of subject-matter topics and was more inclusively worded to serve as a basis for the composite outline.

Sheets, ruled with six vertical columns at the right-hand side, were used for tabulating the frequency of appearance of topics in the five textbooks. A code

letter for each of the five textbooks was placed respectively at the top of one of the first five vertical columns and an (N) was placed in the sixth vertical column. The total number of books in which a particular topic appeared was recorded under (N) in the sixth column.

The following key used for Table I shows the code letters assigned to each of the five physics textbooks:

Letter	Authors	Title
A	Bower and Robinson	Dynamic Physics
B	Dull	Modern Physics
C	Clark, Gorton, and Sears	Physics of Today
D	Whitman-Peck	Physics
E	Black and Davis	Elementary Practical Physics

The topics from the outline of textbook (B) were written in their outline form at the left-hand side of the sheet. An (x) was placed in the column headed by (B) opposite each topic in this section of the outline to indicate that that topic appeared in textbook (B).

When all of the topics from the outline of textbook (B) had been entered, topics from a second textbook were added to the outline in the following manner: an (x) was placed headed by the code letter for this second textbook opposite every topic which appeared in the second textbook and which had already been entered from textbook (B).

In many cases the topics from the second textbook were worded differently from those appearing in textbook (B). If the meaning were the same, the wording from textbook (B) was retained in the composite outline.

When an (x) was placed in the column headed by the code letter of the second textbook (A) for all of the topics which the second textbook had in common with textbook (B), the remaining topics from that book were added at appropriate places to the outline and an (x) was placed in the appropriate column. When all of the topics from the second textbook had been added, a similar procedure was followed with each of the remaining three textbooks.

If the texts did not agree as to the proper major topic for a minor topic to support, but two or more books did agree, then the minor topic was placed in accordance to this. If there was no agreement, then the minor topic was placed under the major topic in the outline of textbook (B) which was selected as a guide.

When all of the topics contained in the five textbooks used for formulating the composite outline had been combined according to the procedure already outlined, the composite outline was re-examined and checked by the investigator to insure that: every topic found in a book was assigned to that book by an (x) placed under its code letter; no topic was assigned to a book which it did not actually contain; and the column (N) had the

correct number of x's for each individual topic.

Three teachers of physics were asked to examine the outline critically, according to Blanchet's[1] procedure, to insure, first, that the position of each topic in the outline was defensible, and secondly, that no topic, although worded differently, appeared more than once in the outline unless the respective difference in its connotations at the two or more points clearly demanded that it be considered as two or more separate topics.

If one of the teachers suggested that a topic be transferred from one position in the composite outline to another, the suggestion was treated in the following manner:

(1) If the topic appeared in the composite outline at the point corresponding with the one where it appeared in the outline of the textbook that contained it, the suggestion to transfer it was disregarded.

(2) If the major topic under which the teacher suggested that the topic in question be placed actually contained a discussion of that topic, then the transfer was made. Major topic refers to the one whose position of relative importance in the composite outline was next above that of the topic question. The suggested

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[1] Waldo Emerson Blanchet, A Basis for the Selection of Course Content for Survey Courses in the Natural Sciences, p. 189. Unpublished Doctor's dissertation, University of Michigan, 1946.

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[1] Waldo Emerson Blanchet, A Basis for the Selection of Course Content for Survey Courses in the Natural Sciences, p. 132. Unpublished Doctor's dissertation, University of Michigan, 1946.

transfer was made in any case if two or more specialists indicated the same point for its placement in the outline.

In all cases in which a minor topic appeared in a textbook though the particular major topic under which it was placed in the outline did not, an (x) was placed beside both the major and the minor topic. If the arrangement of topics in the outline be defensible, then such a procedure would seem defensible. Moreover, it is the only way of avoiding the situation of minor topics having greater composite values than major ones.

Table I, which follows, shows the subject-matter topics tabulated from the various textbooks.

TABLE I

COMPOSITE TOPICAL OUTLINE OF FIVE HIGH-SCHOOL TEXTBOOKS OF PHYSICS

Topics	Book A	B	C	D	E	N
1. Physics in relation to life*	x	x	x	x		4
Physics, a fundamental science		x		x		2
Theory and practice of physics	x	x		x		3
What is "science?"		x				1
Why study physics?				x		1
Is physics difficult?				x		1
Physics versus engineering				x		1
Physics then and now				x		1
Divisions of physics	x	x			x	3
Mechanics	x	x			x	3
Heat	x	x			x	3
Sound	x	x			x	3
Electricity	x	x			x	3
Light	x	x			x	3
Modern Physics				x		1
2. Physics in relation to progress	x			x		2
Period of ignorance, superstition and fear........................	x					1
Rise of critical thinking	x					1
Recognizing the problem	x					1
Tentative ideas	x					1
Reasoning	x		x	x	x	4
Experimentation and observation.........................	x		x	x		3
Conclusion based on experiment..........................	x		x	x	x	4

*Table I is read thus: The major topic "Physics in relation to life" was found in Books A, B, C, and D. The total number of books in which this topic was found was four. The minor topic "Physics, a fundamental science" was found in Books B and D. The total number of books in which the minor topic was found was two. The sub-topic "Mechanics" was found in Books A, B, and E. The total number of books which contained it was three.

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
2. (Continued)						
Telescope and microscope	x	x	x	x	x	5
Steam engine	x	x	x	x	x	5
Steamboat and locomotive	x	x		x		3
Cotton gin and reaper	x					1
Electric generator	x	x	x	x	x	5
Internal-combustion engine	x	x		x	x	4
Automobile and airplane	x	x	x	x	x	5
Radio and motion picture	x	x	x	x	x	5
Benefits of physics	x		x			2
3. Matter and energy	x	x	x	x	x	5
What is matter?	x	x	x	x	x	5
States of matter: solid, liquid, and gas..........................	x	x	x	x	x	5
Structure of matter		x	x	x		3
Changes that take place in matter..............................		x	x			2
Ninety-two elements	x					1
Composition of matter	x	x	x	x	x	5
Divisibility of matter				x		1
Law of conservation	x	x	x	x	x	5
Potential and kinetic energy	x	x	x	x	x	5
4. Properties of matter	x	x	x	x	x	5
General properties	x	x		x		3
Volume	x	x		x		3
Mass	x	x		x		3
Weight	x	x	x	x	x	5
Difference between mass and weight.................	x	x		x	x	4
Sealer of weights and measures......................				x		1
Impenetrability	x	x				2
Inertia	x	x	x	x	x	5
Porosity	x	x		x		3
Special properties	x	x		x		3
Tenacity	x	x	x	x		4
Brittleness	x	x				2
Hardness	x	x		x		3
Annealing	x	x				2
Industrial abrasives	x			x		2
Malleability	x	x	x			3
Meaning of density	x	x	x	x	x	5
Measurement of density	x	x	x	x	x	5
Uses of density	x	x				2

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
5. Measurement	x	x	x	x	x	5
Origin of some common measures				x		1
Advantages of the metric system	x	x		x		3
English system	x	x	x	x	x	5
Units: length, capacity, mass, time....................	x	x	x	x	x	5
Metric system	x	x	x	x	x	5
Units: length, capacity, mass, time....................	x	x	x	x	x	5
6. Liquid pressure and total force	x	x	x	x	x	5
Downward pressure	x	x	x		x	4
Depth and density	x	x	x	x	x	5
Independent of shape or area of container..................	x	x	x	x	x	5
Practical applications	x	x	x			3
Waterhead	x	x		x		3
Independent of direction	x	x	x	x		4
Laws of liquid pressure	x	x	x	x		4
Explanation of direct and inverse proportion.............	x	x				2
Upward and sidewise pressure	x	x	x	x	x	5
Practical applications	x	x	x	x		4
Total force	x	x	x		x	4
On the bottom of a container	x	x	x		x	4
On the side of a container	x	x	x		-	3
How pressure is measured	x	x		x	x	4
Open manometer	x	x		x	x	4
Closed manometer	x	x		x	x	4
Total force as related to construction work..................		x				1
7. Pressure on a confined liquid	x	x	x	x	x	5
Pascal's law	x	x	x	x	x	5
A new machine for multiplying force........................		x				1
Applying external pressure	x	x		x	x	4
Little water - great force	x	x	x			3
Applications of water pressure	x	x	x	x	x	5
Hydraulic press	x	x	x	x	x	5
Water seeks its own level	x	x	x	x	x	5
Artesian well	x	x	x			3
City water system	x			x		2
Automobile brakes	x	x	x	x	x	5
Airplane brakes	x			x		2

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
7. (Continued)						
Submerged bodies must withstand pressure............	x	x		x		3
Submarine	x	x	x	x		4
Deep sea diver	x	x		x	x	4
How liquids transmit pressure.....................	x	x	x		x	4
How hydraulic brakes work	x	x		x		3
Pressure graph			x			1
Dentist's chair	x	x		x	x	4
Barber's chair	x	x		x	x	4
Hydraulic elevator	x	x	x	x	x	5
Automobile hoist	x	x		x	x	4
Hydrostatic bellows		x				1
8. Loss of weight of objects	x	x	x	x	x	5
Archimedes' principle	x	x	x	x	x	5
What is buoyancy of liquids?		x		x		2
Measurement of buoyancy	x	x	x			3
Testing Archimedes' principle	x	x				2
Specific gravity	x	x	x	x	x	5
How to find it	x	x	x	x	x	5
Of solids: heavier and lighter than water........	x	x	x	x	x	5
Of liquids						
Special-bottle method	x	x		x	x	4
Loss-of-weight method		x			x	2
Hydrometer method	x	x	x	x	x	5
Use of the commercial hydrometer.....	x	x	x	x		4
Movement of ships		x				1
Principle of flotation		x	x		x	3
Behavior of floating objects		x	x			2
Floating dry dock		x	x			2
Resistance	x	x	x	x		4
Submarine	x	x	x	x		4
Design	x					1
Rising and sinking	x	x		x		3
Travelling	x	x				2
9. Pressure of air	x	x	x	x	x	5
Weight of air	x	x	x	x	x	5
Matter	x			x	x	3
Torricelli's experiment	x	x	x	x	x	5
How great atmospheric pressure is............................	x	x	x	x		4
The Magdeburg hemispheres	x	x	x	x	x	5

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
9. (Continued)						
Mercurial barometer	x	x	x	x	x	5
Aneroid barometer	x	x	x	x	x	5
Barograph		x	x	x	x	4
Uses of the barometer	x	x	x		x	4
Buoyancy of the air	x	x	x	x	x	5
Balloon	x	x	x	x	x	5
Dirigible	x	x	x	x	x	5
Uses of hydrogen	x	x	x			3
Uses of helium	x	x	x	x	x	5
Lift pump	x	x	x	x	x	5
Force pump	x	x	x	x	x	5
Chain pump		x				1
Siphon	x	x	x	x	x	5
Aspirating siphon		x				1
10. Wind, water, and weather	x	x	x	x		4
Effects of the weather		x		x		2
Work of the weather bureau	x			x	x	3
Extent of the atmosphere	x	x	x	x	x	5
Zones in the atmosphere	x	x		x	x	4
Troposphere	x	x		x	x	4
Stratosphere	x	x	x	x	x	5
Ozonosphere				x		1
Ionosphere				x		1
Weather instruments	x	x	x	x	x	5
Barometer for pressure	x	x	x	x	x	5
Anemometer for wind velocity....................	x			x		2
Weather vane for wind direction.................	x	x	x	x		4
Sling psychrometer for humidity.................	x	x		x		3
Sunshine recorder				x		1
Rain gauge				x		1
Sources of moist air				x		1
Removal of moisture from air	x			x		2
Dew point	x	x	x	x	x	5
Frost point	x			x		2
Precipitation	x	x		x		3
Measurement of precipitation.............	x	x		x		3
An anti-cyclone		x		x		2
An adventure in the stratosphere.......................				x		1
Freak performances of tornadoes.....................			x	x		2

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
11. Expansibility and compressibility of gases............................	x	x	x	x	x	5
Effect of pressure	x	x	x	x	x	5
Relation of volume to pressure..........................	x	x	x	x	x	5
On gas densities		x				1
Kinetic theory of a gas			x	x	x	3
Gases expand		x	x	x	x	4
What are standard pressure and temperature?............		x			x	2
Liquids not easy to compress		x		x		2
Uses of carbon dioxide				x		1
The oxy-acetylene torch				x		1
Boyle's law	x	x	x	x	x	5
Density of gases	x	x			x	3
Cartesian diver	x	x		x		3
Fire extinguisher		x	x			2
Graphic showing	x	x				2
A vacuum by condensing steam				x		1
Nature abhors a vacuum		x		x	x	3
Uses of the vacuum pump	x	x		x	x	4
Electric light bulb		x		x	x	3
X-ray bulbs		x			x	2
Radio tubes	x	x		x	x	4
Thermos bottle	x	x	x	x	x	5
Milking machine		x				1
Vacuum pans		x			x	2
Vacuum cleaner	x	x		x	x	4
Why liquids rise in exhausted tubes............		x			x	2
12. Compressed air	x	x	x	x	x	5
Compression pump	x	x	x	x		4
The diving bell		x	x			2
The diving suit		x				1
Pneumatic caisson		x	x	x	x	4
What is the aspirator?		x				1
The ejector		x				1
Atomizer		x		x		2
Ventilation of tunnels		x				1
Measurement of pressure	x	x	x	x	x	5
Tire gauge	x	x				2
Measurement of volume	x	x	x	x	x	5
Gas meter	x	x		x		3
Westinghouse air brakes	x	x	x			3
Reading the meter dials				x		1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
13. Behavior of matter	x	x	x	x	x	5
Molecular theory	x	x	x	x	x	5
Brownian movement	x	x	x	x	x	5
Process of diffusion	x	x		x	x	4
Through solids	x	x				2
Through liquids	x	x				2
Through membranes	x	x		x		3
Osmosis	x	x		x		3
Diffusion of liquids slower than that of gases	x	x			x	3
14. Molecular attraction	x	x	x	x	x	5
Cohesion and adhesion	x	x	x	x	x	5
Comparison of solids, liquids, and gases.............		x				1
Relation to structure	x	x	x			3
Elasticity	x	x	x	x	x	5
Perfect elasticity		x	x		x	3
Elastic limit		x	x	x	x	4
Factor of safety	x	x		x		3
Hooke's law	x	x	x	x	x	5
Stress and elasticity: tension, compression, shearing, strain........................	x	x		x	x	4
Relation to liquids	x	x	x	x	x	5
Surface tension	x	x	x	x	x	5
Viscosity of liquids .		x		x	x	3
Shape of liquid surfaces	x	x	x	x		4
Concave	x	x				2
Meniscus		x	x			2
Convex	x	x				2
Capillarity	x	x	x	x	x	5
Laws of capillarity		x	x			2
Phenomena in everyday life.....................	x	x		x		3
Capillarity action in soils....................	x	x	x	x	x	5
Stresses	x	x		x	x	4
Materials used in industry	x					1
Of airplanes	x		x			2

TABLE (CONTINUED)
I

Topics	A	B	C	D	E	N
15. The nature of a solution		x	x			2
Facts concerning solutions		x	x			2
Solvent		x	x			2
Solute		x	x			2
Nature of crystallization		x	x			2
How liquids are dissolved		x				1
Miscible liquids		x	x			2
Immiscible liquids		x	x			2
Emulsion		x	x			2
How gases are adsorbed by solids......................		x		x	x	3
How gases are absorbed by liquids.....................		x		x	x	3
Henry's law	x	x				2
16. Force of gravity	x	x	x	x	x	5
Law of gravitation	x	x	x	x	x	5
Center of gravity	x	x	x	x	x	5
Condition of stability		x			x	2
Finding the center of gravity..................		x	x		x	3
Equilibrium	x	x	x	x	x	5
Stable		x	x	x		3
Unstable		x	x	x		3
Neutral		x	x	x		3
Moments of force	x	x	x	x	x	5
Weighing the earth				x		1
The Cavendish apparatus	x			x		2
17. Magnitude of two or more forces	x	x	x	x	x	5
What is a force?	x	x	x	x	x	5
Graphic representation of a force.....................	x	x	x	x	x	5
Parallel forces	x	x	x	x	x	5
Law of parallel forces		x	x	x		3
The couple		x	x			2
Moment of a force	x	x	x	x	x	5
Center of moments		x	x	x	x	4
Use of the principle of moments..................	x	x				2
Composition of forces	x	x	x	x	x	5
Resultant of forces	x	x	x	x	x	5
Forces acting at right angles..................	x	x		x	x	4
Forces acting at any angle	x	x	x	x	x	5
Three forces at a point		x	x		x	3
Equilibrant	x	x	x	x	x	5

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
17. (Continued)						
Analyzing a single force	x	x				2
Automobile affected by gravity going uphill...........	x	x				2
Sailboat moving against the wind......................	x	x		x	x	4
18. Resolution of forces			x	x	x	3
Finding a desired component		x	x			2
Practical applications			x	x	x	3
The street lamp bracket			x		x	2
The truss			x			1
The roof truss			x			1
A bridge truss			x			1
Forces due to wind		x	x	x		3
Carpet sweeper				x		1
How the door catch works				x		1
The lawn mower		x		x	x	3
19. Accelerated motion	x	x	x	x	x	5
Calculation	x	x	x	x	x	5
Centripetal acceleration			x			1
Galileo's experiment			x	x	x	3
Velocity at any given time	x	x	x	x	x	5
Resolution of velocities			x	x		2
Force of gravity	x	x	x	x	x	5
Method of computing accelerated motion...............	x	x	x	x		4
Body in motion	x	x	x	x		4
Laws of acceleration	x	x		x	x	4
Application to freely falling bodies...........		x		x	x	3
In a vacuum		x	x		x	3
Acceleration	x	x	x	x	x	5
Positive	x	x		x	x	4
Negative	x	x		x	x	4
Application to bodies projected upward......		x				1
Overcoming acceleration	x			x		2
The parachute	x			x		2
20. Newton's laws of motion	x	x	x	x	x	5
Units of force	x	x	x	x	x	5
Gravitational units: pound, gram........................	x	x	x	x	x	5
Absolute units: dyne, poundal	x	x	x			3
Law of universal gravitation	x	x	x	x	x	5

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
20. (Continued)						
Weight and the earth's rotation	x	x	x	x	x	5
Momentum	x	x	x	x	x	5
The fall of projectiles	x	x		x	x	4
Bombs	x			x		2
Recoil of a gun	x	x		x	x	4
Application of reaction		x		x		2
Rotary lawn sprinkler		x				1
Disappearing coast gun		x				1
Proof of the earth's rotation				x		1
Bernoulli's principle	x	x		x	x	4
Applications	x	x		x		3
Baseball curves		x		x	x	3
Venturi meter		x				1
21. Curvilinear motion	x	x	x	x	x	5
Path of a projectile is curved	x	x		x	x	4
Firing horizontally	x	x		x	x	4
Firing at an angle		x				1
Range		x				1
Trajectory		x		x		2
Angle of elevation		x				1
Finding the composition of velocities.......................		x	x	x		3
Centripetal force	x	x	x	x	x	5
Centrifugal force	x	x	x	x	x	5
Mass of object	x	x	x		x	4
Speed object travelling	x	x	x		x	4
Radius of rotation	x	x	x		x	4
Earth flattened at poles	x			x		2
Cream separator	x	x	x	x		4
Centrifugal water pump	x	x		x	x	4
Governor of a steam engine	x	x		x		3
Centrifugal tachometer	x	x				2
Rate-of-turn indicator	x	x	x			3
Directional gyro	x			x		2
Counteracting the effects of centrifugal force...........		x				1
Calculating its magnitude		x			x	2
Principle of the gyroscope		x	x	x		3
Gyrostabilizer		x	x	x		3
Gyrocompass		x	x	x		3
Sperry electronic gyropilot				x		1
Gyro-horizon				x		1

TABLE (CONTINUED)
I

Topics	A	B	C	D	E	N
22. Swinging pendulum	x	x	x	x	x	5
The simple pendulum	x	x	x	x		4
Center of suspension		x		x		2
The metronome				x		1
The compound pendulum		x				1
Center of oscillation		x	x	x		3
Center of percussion		x	x	x		3
Simple vibration of a pendulum	x	x	x	x		4
Causes for swinging	x					1
Laws of the pendulum	x	x	x	x		4
Calculations	x	x	x			3
Use in a clock	x	x		x		3
Period	x	x	x	x		4
Amplitude	x	x	x	x		4
Frequency	x	x				2
23. Scientific meaning of work	x	x	x	x	x	5
Measurement of work	x	x	x	x	x	5
Principle of work		x	x	x	x	4
Definition of work units	x	x	x			3
Gravitational units	x	x	x	x	x	5
Absolute units	x	x	x			3
What is power?		x	x	x	x	4
Units of power	x	x	x	x	x	5
Horsepower	x	x	x	x	x	5
Watt	x	x	x	x	x	5
24. Principle of conservation of energy..............................	x	x	x	x	x	5
What is energy?	x	x	x	x		4
Potential energy	x	x	x	x	x	5
Kinetic energy	x	x	x	x	x	5
Effect of speed	x	x				2
Measurement of energy	x	x	x	x	x	5
Dissipation of energy					x	1
Effect of speed in stopping an automobile...............	x	x				2
Energy of a moving bullet	x	x	x			3
Transformation of energy	x	x	x	x	x	5
Perpetual motion machine	x		x			2
25. Aid of machines in doing work	x	x	x	x	x	5
Development of large forces	x	x				2
Why men invent machines	x	x				2
General law of machines	x					1
Classes of levers		x	x	x	x	4

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
25. (Continued)						
Mechanical advantage	x	x	x	x	x	5
Velocity ratio	x					1
Speed gain	x					1
Modern strip mining				x		1
Installing a power grinder				x		1
26. Mechanical advantages of machines	x	x	x	x	x	5
Meaning of mechanical advantage		x	x			2
Measurement	x	x	x	x	x	5
Wheel and axle	x	x	x	x	x	5
Uses		x	x		x	3
Applications		x	x		x	3
The capstan		x	x		x	3
The windlass		x		x	x	3
The hoisting derrick		x			x	2
Grinding wheel				x		1
Wheelbarrow in China				x		1
The pulley	x	x	x	x	x	5
What is a pulley?	x	x	x			3
Uses of the pulley		x	x		x	3
Use of single fixed pulley		x			x	2
Use of single movable pulley......................		x			x	2
System of pulleys	x	x	x		x	4
Differential pulley	x	x	x	x		4
Inclined plane	x	x	x	x	x	5
Calculating the grade of a hill..................	x	x			x	3
Wedge	x	x	x	x	x	5
Screw	x	x	x	x	x	5
Pitch of the screw	x	x	x	x	x	5
Uses of the screw		x	x		x	3
Letter press		x	x			2
Vise		x	x			2
Jackscrew		x		x	x	3
Spherometer		x				1
Micrometer caliper		x			x	2
Wood screws				x	x	2
27. Compound machines		x	x		x	3
What is a compound machine?		x				1
Train of gear wheels	x	x				2
Steam shovel		x	x			2
Automobile transmission	x	x			x	3
The differential	x	x	x	x		4
The worm gear	x	x				2

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
27. (Continued)						
The water wheel		x	x		x	3
Overshot type		x	x	x	x	4
Undershot type		x		x	x	3
Pelton water wheel		x		x	x	3
Water motor		x		x		2
Motor turbine	x	x	x	x	x	5
28. Friction	x	x	x	x	x	5
Control of friction	x	x	x			3
How friction helps us		x	x	x	x	4
How friction is a hindrance		x		x		2
Nature of friction	x	x				2
Movement involved	x					1
Automobile clutch	x		x	x		3
Automobile brake	x	x	x	x		4
Sewing machine			x			1
Frictional force	x	x		x	x	4
Coefficient of friction	x	x		x	x	4
Rolling friction	x	x	x	x		4
Starting friction				x		1
Sliding friction	x	x	x	x		4
Laws of sliding friction..................		x				1
Fluid friction less than solid friction...........		x				1
Reduction of friction	x	x		x	x	4
Polish the bearings		x		x		2
Use anti-friction metals...................		x				1
Use ball or roller bearings..............	x	x	x	x		4
Use a lubricant	x	x	x	x	x	5
Increase of friction: sand, chains, rosin, rubber		x		x		2
29. Efficiency of machines	x	x	x	x	x	5
Measurement	x		x	x	x	4
What is efficiency?	x	x			x	3
Transfer of energy	x	x	x	x		4
Efficiency of a car		x				1
Of water wheels		x	x			2
Friction and the efficiency of machines......................			x		x	2

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
30. Nature of heat	x	x	x	x	x	5
What is heat?	x	x			x	3
Fire and civilization				x		1
Sources of heat	x	x		x	x	4
The sun	x	x	x	x	x	5
The earth's interior		x			x	2
Chemical action	x	x		x	x	4
Electrical energy				x	x	2
Mechanical energy		x		x		2
Friction	x	x	x	x		4
Impact		x				1
Compression		x				1
Difference between heat and temperature....................	x	x		x		3
Unreliability of our temperature sense....................		x	x	x		3
How an air thermometer works		x		x		2
How the mercury thermometer is made..........................		x				1
Limitations of the mercury thermometer.................		x				1
How the thermometer is graduated	x	x		x	x	4
31. Change of temperature of matter	x	x	x	x	x	5
Heat makes solids expand	x	x	x	x	x	5
Comparison of Centigrade and Fahrenheit scales..............	x	x	x	x	x	5
Special thermometers	x	x	x	x	x	5
Clinical	x	x	x	x	x	5
Metallic	x	x	x	x	x	5
Maximum		x				1
Minimum		x				1
Maximum and minimum	x	x	x	x	x	5
Thermograph	x	x		x		3
32. Measuring expansion caused by heat	x	x	x	x	x	5
Coefficient of linear expansion	x	x	x	x	x	5
Coefficient of volume expansion	x	x			x	3
Expansion of liquids and gases	x	x	x		x	4
Peculiarity of expansion of water......................	x	x		x	x	4
How expansion affects density......................		x	x			2
Meaning of absolute temperature......................	x	x	x	x	x	5
Expansion of gases in cooking.......................			x			1

TABLE (CONTINUED)
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Topics	Book A	B	C	D	E	N
32. (Continued)						
Temperature and pressure	x			x		2
Charles's and Gay-Lussac's laws	x	x	x	x	x	5
Charles's law shown graphically........................		x	x			2
Problems involving its use	x	x	x		x	4
Law of Charles and Boyle combined..................		x	x	x	x	4
The effect of unequal heating		x	x		x	3
Expansion of solids made useful		x	x		x	3
How engineers cope with the expansion problem................		x				1
How radiator valves work		x		x		2
Uses of the compound bar		x	x	x	x	4
Metallic thermometer	x	x	x	x	x	5
The thermostat	x	x	x	x	x	5
The balance wheel	x	x	x		x	4
Use of elinvar		x				1
The pendulum compensated for temperature changes............		x	x			2
Mercury type		x	x			2
Compensating rod type		x				1
33. Measurement of heat	x	x	x	x	x	5
Units: British thermal, metric-calorie........................	x	x	x	x	x	5
Effect of heat upon temperature	x	x	x	x	x	5
Difference between heat and temperature.................		x		x		2
Specific heat	x	x	x	x	x	5
Measurement of specific heat.....................	x	x	x	x	x	5
How high specific heat of water affects us.........		x				1
34. Heat of fusion	x	x	x	x	x	5
What is the heat of fusion?	x	x				2
Heat of fusion of ice measured	x	x	x	x	x	5
Heat given out when water freezes...........................	x	x	x	x	x	5
Heat is absorbed in solution	x	x		x		3
The volume change upon solidification......................	x	x			x	3
How the expansion of water upon freezing helps us..............	x	x		x	x	4
Influence of bodies of water on freezing.....................			x		x	2

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
34. (Continued)						
Laws of melting					x	1
Freezing by boiling					x	1
35. Heat and the state of matter	x	x	x	x	x	5
Kinetic theory of heat		x	x			2
Effect of heat	x	x	x	x	x	5
Variation of substances in heat capacity...............		x				1
Laws of heat exchange		x	x			2
Lowering the freezing point	x	x	x	x	x	5
Dissolving of salts	x	x	x			3
Pressure increase	x	x	x	x	x	5
Amount of heat needed to melt one gram of ice........		x			x	2
Boiling point and pressure	x	x	x	x	x	5
Steam boiler	x	x		x	x	4
Pressure cooker	x	x	x	x	x	5
Laws of boiling		x	x			2
Boiling point of liquids					x	1
Distillation	x	x	x	x	x	5
Fractional distillation	x	x	x	x	x	5
Destructive distillation		x				1
What is vaporization?	x	x	x		x	4
Heat of vaporization: measurement...........................	x	x	x	x	x	5
Heat needed to change a gram of water into steam.........					x	1
Sublimation	x	x		x		3
Rate of evaporation of liquids	x	x	x	x		4
Molecular action of liquids				x		1
Effect of temperature	x	x	x	x		4
Effect of area		x	x			2
Nature of liquid		x				1
Effect of air above liquid surface......................	x	x	x	x		4
Effect of humidity		x				1
Effect of wind	x	x				2
Saturated and unsaturated vapors......................	x		x	x	x	4
Evaporation a cooling process	x	x	x	x	x	5
Principle used in making ice		x				1
Effect of heat on water shown graphically...................		x		x		2
Rain, dew, and frost	x		x	x	x	4
Hail			x			1
Sleet			x			1

TABLE (CONTINUED)
I

Topics	A	B	C	D	E	N
			Book			
35. (Continued)						
Cause of precipitation	x	x		x		3
Meaning of "dew point"	x	x	x	x	x	5
Humidity	x	x	x	x	x	5
Absolute humidity	x	x		x		3
Relative humidity	x	x	x	x	x	5
How temperature affects relative humidity........	x	x	x		x	4
Practical importance of determining humidity.............					x	1
Hygrometer	x	x		x	x	4
Hygrodeik thermometer	x	x				2
Wet-and-dry-bulb thermometer	x	x		x	x	4
Effective temperature				x		1
36. Convection	x	x	x	x	x	5
Hot-air	x	x	x	x	x	5
Hot-water	x	x	x	x	x	5
Chimney smoke	x	x	x			3
Steam heat		x		x	x	3
Vapor heat		x		x		2
Comparison of heating systems		x				1
How we shall ventillate		x	x		x	3
What is air conditioning?		x	x	x		3
The stove				x		1
Automatic fuel feeders				x		1
37. Conduction	x	x	x	x	x	5
Heat through solids	x	x	x		x	4
Conductometer		x				1
Heat through liquids		x	x		x	3
Good and poor conductors	x	x	x		x	4
Gases are very poor conductors......................		x	x		x	3
How conductivity affects our temperature sense..............		x				1
How clothing keeps us warm	x	x				2
Utilizing conduction		x			x	2
Using insulators to save heat	x	x	x	x	x	5
How modern gas ranges save heat		x		x		2
The thermos bottle conserves heat		x	x	x	x	4
The refrigerator is a heat insulator............................	x	x		x	x	4
38. Radiation	x	x	x	x	x	5
What is radiation?		x	x		x	3
Laws of radiation		x				1

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
38. (Continued)						
Newton's law of cooling		x				1
From sun to earth	x	x				2
"Waves" in a vacuum	x					1
Industrial uses of radiant heat				x		1
What warms the cold frame?				x		1
39. Absorbers, radiators, and reflectors of heat	x	x	x	x	x	5
Absorbers: dark-colored materials	x	x	x	x	x	5
Reflectors: polished surfaces	x	x	x		x	4
The thermos bottle	x	x	x	x	x	5
Cooking by a reflection oven			x			1
Radiators: dark-colored materials	x	x	x	x	x	5
Crookes' radiometer	x	x	x		x	4
Leslie's cube and a differential thermometer		x				1
What is heat transparency?		x			x	2
Diathermanous substance		x			x	2
Athermanous substance		x			x	2
40. Study of meterorology	x			x		2
Weather conditions	x	x		x		3
Meteorological elements	x					1
United States Weather Bureau	x			x	x	3
Data at ground level	x					1
Data from high altitudes: the radiosonde	x			x		2
Examining the clouds	x					1
Description and classification	x					1
Making weather maps	x	x				2
Isobars		x	x	x	x	4
Isotherms		x				1
Meaning of symbols		x				1
Interpretation		x				1
Cold fronts	x	x		x		3
Warm fronts	x	x		x		3
Stationary front				x		1
Occluded front				x		1
Causes of winds	x	x		x		3
Monsoons		x				1
Trade winds	x	x	x	x		4

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
40. (Continued)						
Equatorial calms	x	x		x		3
Horse latitudes	x	x		x		3
The westerlies	x			x		2
Land and sea breezes	x	x				2
Meaning of air masses	x			x		2
Behavior	x	x		x		3
Importance of fronts	x					1
Stable and unstable air	x					1
Atmospheric waves	x					1
Cyclonic storm	x	x	x	x		4
41. Relation between heat and work	x	x	x	x	x	5
Fuels and mechanical work			x			1
Mechanical equivalent of heat	x	x	x	x	x	5
Joule's experiment	x	x	x	x	x	5
Theory of transformation	x	x				2
Mechanical refrigeration	x	x	x	x	x	5
In modern life	x					1
The electric refrigerator	x	x	x	x	x	5
The gas refrigerator	x	x	x	x	x	5
How gases are liquified		x		x		2
How liquid is made		x		x		2
Quick freezing	x			x		2
Frozen food lockers				x		1
The use of cold				x		1
Converting heat into work		x				1
In our own bodies		x				1
By the use of steam		x				1
In internal-combustion engines........................	x	x		x	x	4
Building an igloo				x		1
42. Utilizing heat	x	x	x	x	x	5
The steam engine	x	x	x	x	x	5
Importance of the steam engine					x	1
High-pressure engine	x	x	x	x	x	5
Low-pressure engine	x	x			x	3
How the steam engine works	x	x	x	x		4
Control of the valves	x	x		x	x	4
Slide valve	x	x		x	x	4
Curliss valves		x				1
Compound engine		x	x		x	3
Providing boiler efficiency		x		x	x	3
Water-tube type		x		x	x	3
Fire-tube type		x		x	x	3
How engineers save fuel		x				1

TABLE (CONTINUED)
I

Topics	A	B	C	D	E	N
42. (Continued)						
Baffle walls		x				1
Feed water heater		x				1
Economizer		x				1
Efficiency of boilers	x				x	2
Efficiency of the steam plant					x	1
Horsepower of an engine	x					1
How the steam turbine works	x	x	x	x	x	5
The steam turbine versus the reciprocating steam engine..		x	x	x	x	4
Curtis turbine		x				1
Parsons and Westinghouse turbines....................		x		x		2
Atomic power: nuclear fission				x		1
The kerosene engine		x			x	2
43. How the internal-combustion engine works............................	x	x	x	x	x	5
The gasoline engine	x	x	x	x	x	5
Burning gas				x		1
Knocking				x		1
High-test fuel				x		1
Safety gasoline				x		1
Utilizing the force of explosion......................	x	x	x	x	x	5
Carburetor	x	x	x	x	x	5
Cooling the gas engine		x		x	x	3
Advantages and disadvantages of the gas engine...........		x				1
The Diesel engine	x	x	x	x	x	5
Semi-Diesel engine		x				1
Efficiency of Diesels				x	x	2
Uses of Diesel engines				x		1

TABLE (CONTINUED)
I

Topics	A	B	C	D	E	N
	Book					
44. Sound and wave motion	x	x	x	x	x	5
Why study sound?					x	1
Source of sound	x	x	x	x	x	5
Effect of vibrations on the air..........................			x			1
Sounds in daily life			x	x		2
How sound waves get to our ears	x	x	x	x	x	5
No sound through a vacuum	x	x		x	x	4
The ear is a receiver of sound waves..........................		x	x	x	x	4
Structure of the ear			x	x	x	3
Perception of sound		x	x		x	3
How to insulate against sound	x	x		x		3
Velocity of sound	x	x	x	x	x	5
Velocity of sound in other media..........................	x	x	x	x	x	5
Depends upon elasticity of medium......................	x					1
Depends upon density of medium......................	x					1
Velocity in relation to temperature..........................	x	x	x	x	x	5
Meaning of sound ranging		x				1
Meaning of vibration	x	x				2
Amplitude	x	x			x	3
Frequency	x	x	x		x	4
Period		x				1
Kinds of vibration	x	x		x	x	4
Transverse	x	x		x	x	4
Longitudinal	x	x	x	x	x	5
Longitudinal wave in a spring....................	x		x	x	x	4
Sound waves are longitudinal	x	x		x	x	4
Condensation	x	x	x	x	x	5
Rarefactions	x	x	x	x	x	5
Measuring sound waves		x				1
Relation of velocity, wave length and vibration...........	x	x	x	x	x	5
Experiment with Savant's toothed wheels.....................				x		1
Graphic representation of sound waves..........................	x					1
Comparison between different kinds of wave motion...........	x	x	x	x		4

TABLE (CONTINUED)
I

Topics	Book A	B	C	D	E	N
45. Reflection of sound	x	x	x	x	x	5
Finding the direction of sound					x	1
How echoes are produced	x	x		x	x	4
Definition of an echo		x				1
Making echoes useful	x	x	x		x	4
Determining the depth of the water................	x	x		x	x	4
The fathometer					x	1
Determining the nearness to a rocky coast.........	x	x				2
Disadvantages of this method................	x	x				2
Vessels receiving submarine signals.............		x			x	2
Finding the altitude of an airplane..............	x					1
Sonic altimeter	x					1
Radio altimeter	x	x				2
Detecting approaching airplanes...................			x			1
Reflection of sound waves from air layers.............	x					1
Acoustic properties of buildings......................	x	x		x	x	4
Importance to speakers	x	x		x	x	4
Reverberation	x	x	x	x	x	5
How to reduce it	x		x	x	x	4
What are whispering galleries?	x	x	x	x		4
Bending of sound waves	x					1
Photography of sound waves	x	x	x		x	4
Sound waves spread out in all directions....................	x	x	x	x	x	5
46. Loudness and pitch	x	x	x	x	x	5
How sounds differ		x				1
Fundamental properties: loudness, pitch, quality........	x	x	x	x	x	5
Meaning of intensity and loudness........................	x	x		x	x	4
Intensity depends upon	x	x			x	3
Distance from origin	x	x		x	x	4
Amplitude of vibration	x	x		x	x	4
Density of the medium	x					1
Area of the vibrating body	x	x	x			3
Loudness of sound	x	x		x	x	4
Inversely proportional to the square of the distance from the source..........	x	x		x		3

TABLE (CONTINUED)
I

Topics	A	B	C	D	E	N
46. (Continued)						
Depends upon the medium		x			x	2
Special conditions affecting loudness........................	x	x	x	x	x	5
Megaphone	x	x	x	x	x	5
Phonograph horn		x				1
Automobile horn		x	x			2
Speaking tube	x	x	x		x	4
Sound reflectors		x	x	x	x	4
Amplifying horns		x		x		2
Ear trumpet		x				1
Stethescope		x	x			2
How loudness is measured: bel, decibel..........................	x	x	x	x	x	5
Approximate loudness of common sounds..................				x	x	2
Pitch of sounds	x	x	x	x	x	5
Dependent on frequency of vibration..................	x	x	x		x	4
Independent of loudness and quality.....................		x				1
Rises as the frequency increases.......................	x	x		x		3
Falls as the wave length increases......................	x	x				2
Using the siren disk	x	x	x		x	4
Definition of pitch	x	x	x		x	4
Doppler's principle	x	x	x	x		4
Auto horn	x	x	x	x		4
Locomotive	x					1
47. Resonance and interference	x	x	x	x	x	5
What are forced vibrations?	x	x			x	3
Intensity of sound increases		x		x		2
What are sympathetic vibrations?	x	x	x	x	x	5
Tuning a radio		x				1
Demonstration with tuning forks.......................		x		x	x	3
What is resonance?	x	x	x	x	x	5
Definition of resonance		x			x	2
Resonance by tuning forks	x	x	x	x	x	5
Resonance in air columns	x	x	x	x	x	5
Closed tubes	x	x		x	x	4
Longer closed tubes	x					1
Open tubes	x	x	x	x	x	5
Spherical resonators	x					1

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
47. (Continued)						
Resonance, wave length, and frequency....................	x		x			2
Interference of sound waves	x	x	x		x	4
Definition of interference		x				1
Producing beats	x	x	x	x	x	5
Definition of a beat		x		x	x	3
Beats and discords	x		x	x	x	4
Condensation reflected as a rarefaction at the end of an open tube......................	x					1
48. Music and quality	x	x	x	x	x	5
Diatonic scale	x	x		x		3
Major triad	x	x		x	x	4
Major chord	x	x	x	x		4
Major diatonic scale	x	x	x	x	x	5
Minor diatonic scale				x		1
Chromatic scale	x	x	x			3
Chromatic semitones	x	x				2
Even-tempered scale	x	x	x	x		4
Comparison of chromatic and tempered scales.............	x	x				2
Intervals			x	x		2
What is standard pitch?	x	x			x	3
Middle-C tuning forks	x	x	x	x	x	5
Concert pitch		x		x		2
International pitch	x	x				2
Difference between noise and music..........................	x	x		x	x	4
Producing a musical note	x	x			x	3
Producing a jarring noise	x	x			x	3
Causes of harmony and discord		x		x	x	3
Limit to the number of vibrations heard....................	x	x		x	x	4
Upper limit of audibility	x	x		x	x	4
Lower limit of audibility	x	x		x	x	4
Supersonics		x			x	2
49. Quality of sounds	x	x	x	x	x	5
Meaning of fundamental	x	x	x	x	x	5
What are overtones?	x	x	x	x	x	5
Definition of an overtone		x	x			2
Dependence on number of overtones present	x	x	x		x	4
Dependence on prominence of overtones......................	x	x	x		x	4

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
50. Musical instruments	x	x	x	x	x	5
What are stringed instruments?	x	x	x	x	x	5
Laws of vibrating strings	x	x	x	x	x	5
Law of lengths	x	x	x	x	x	5
Law of diameters		x		x	x	3
Law of tensions	x	x	x	x	x	5
Law of densities	x	x		x		3
Use of the sonometer	x	x	x	x	x	5
Vibration of a string	x	x	x	x	x	5
Vibration of a free rod			x			1
How the piano works				x	x	2
How organ pipes produce sound		x	x	x	x	4
Closed pipe	x	x	x	x	x	5
Open pipe	x	x	x	x	x	5
Pitch of a pipe	x	x		x		3
Nodes and antinodes in the organ pipe..................	x		x			2
Overtones produced by pipes	x	x	x			3
The electric organ		x		x	x	3
How wind instruments produce sound...........................	x	x	x	x	x	5
Types of wind instruments	x	x	x	x	x	5
Vibrations of bells and plates......................		x				1
Vibrating air cavities				x		1
Whistle			x	x		2
Straw squawker			x			1
Vibrating membranes produce sound	x	x	x		x	4
The human voice	x	x	x	x	x	5
The glotis				x		1
Principle of the phonograph	x	x	x	x	x	5
Edison's original talking machine.....................				x		1
The dictating machine		x	x	x		3
Dictaphone		x				1
Ediphone		x				1
Cutting records electrically		x	x			2
Sound waves shown graphically		x				1
Vibrograph		x				1
Manometric flame	x	x				2
Phonodeik		x		x		2
Oscillograph		x		x		2
Analyzing and reproducing sounds	x	x				2
Helmholtz resonators	x	x			x	3

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
51. Nature and velocity of light	x	x	x	x	x	5
What is the nature of light?	x	x	x	x	x	5
Importance of light to man	x	x	x		x	4
Good and bad effects of light....................					x	1
Light does work			x			1
Light is another form of energy..................			x	x	x	3
Light produces mechanical motion.................			x			1
Use of light in plant life			x			1
Theories of light	x	x		x	x	4
Huygens' wave theory of light	x	x		x	x	4
Newton's corpuscular theory	x	x		x	x	4
James Clerk-Maxwell's electromagnetic theory..........	x			x		2
Max Planck's quantum theory	x	x		x	x	4
Einstein's theory of relativity.....................	x	x			x	3
Difference between light waves and sound waves................	x	x	x		x	4
Showing that light waves are transverse..................	x		x	x	x	4
Sources of light	x	x	x	x		4
Natural light	x	x	x	x		4
Artificial light	x	x		x		3
Difference between luminous and illuminated objects...........	x	x		x		3
Luminous body	x	x		x		3
Stars		x	x			2
Flame of a candle				x		1
Sun	x	x	x	x		4
Electric light	x		x			2
Illuminated body		x	x			2
Most planets		x	x			2
Moon	x	x	x	x		4
Meaning of reflection of light	x	x	x	x	x	5
Smooth water		x	x	x	x	4
Panes of glass	x	x				2
Highly polished metals		x	x	x	x	4
Planet Venus reflects 50% of light received.............		x				1
Planet Mars reflects less than 25% of light incident upon it....................		x				1
Meaning of absorption of light	x	x		x		3

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
51. (Continued)						
Dark-colored objects are good absorbers of light	x	x		x		3
Meaning of transmission of light	x	x	x		x	4
Transparent objects	x	x	x	x	x	5
Air		x	x			2
Water	x	x	x			3
Glass	x	x	x			3
Transluscent objects	x	x		x		3
Oiled paper		x				1
Frosted electric bulbs	x	x	x	x		4
Some lamp shades		x				1
Opaque objects	x	x	x	x	x	5
No transmission of light	x	x	x	x	x	5
Rays, beams, and pencils of light..........................	x	x				2
Cause of shadows: umbra, penumbra..........................	x	x	x	x	x	5
Cause of eclipses	x	x	x	x	x	5
The sun's corona		x	x			2
Stages in total eclipse of sun......................			x			1
Velocity of light	x	x	x	x	x	5
Galileo's method to determine velocity of light......	x	x	x	x		4
Roemer's method of calculating velocity of light......	x	x	x	x	x	5
Michelson's use of the mile-long vacuum tube............	x	x		x	x	4
Michelson's use of the octagonal mirror................	x	x		x	x	4
Greater in air than in water		x	x	x	x	4
Greater in a vacuum than in air.......................		x	x	x	x	4
52. Photometry	x	x	x	x	x	5
Meaning of intensity and illumination......................	x	x		x		3
Candle power	x	x	x	x	x	5
Foot-candle	x	x	x	x	x	5
Law of illumination	x	x			x	3
How light is measured	x	x	x	x	x	5
Standard candle measures intensity of light............	x	x		x	x	4
Foot-candle is used to measure illumination............	x	x	x	x	x	5
Definition of the foot-candle..................	x	x	x	x	x	5
The lumen is used in illumination engineering.........		x		x		2

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
52. (Continued)						
Efficiency of a lamp	x			x	x	3
Amount of light we need	x	x		x	x	4
How we can economize		x	x			2
Measurement of candle power	x	x	x	x	x	5
Bunsen or grease-spot photometer....................	x	x	x	x	x	5
Law of intensity of light	x	x	x	x	x	5
Use of the Bunsen photometer....................					x	1
Joly photometer		x				1
Student use		x				1
Spherical photometer: commercial use..................		x				1
Photoelectric foot-candle meter........................	x	x		x	x	4
53. Reflection of light waves	x	x	x	x	x	5
Factors governing the reflection of light..................	x	x	x	x		4
Nature of the material	x	x	x	x		4
Polish of the surface	x	x				2
Angle at which light strikes the surface................	x	x				2
Law of reflection	x	x		x	x	4
Regular reflection	x	x	x	x	x	5
Diffused reflection	x	x	x	x	x	5
How diffusion of light is promoted.....................		x	x		x	3
By reflection	x	x	x	x	x	5
Semi-gloss paper		x				1
Full-gloss paper		x				1
Glazed wall paper		x				1
By transmission		x			x	2
54. What is a mirror?	x	x		x	x	4
Concave mirror	x	x	x	x	x	5
Convex mirror	x	x		x	x	4
How waves are affected by curved mirrors.................	x					1
Kinds of images: real, virtual	x	x	x	x	x	5
By reflection of rays	x	x				2
How small openings form images		x	x	x		3
Pinhole camera		x	x	x		3
Kinds of images formed by plane mirrors........................	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
			Book			
54. (Continued)						
Uses of plane mirrors		x			x	2
Looking glass	x	x	x	x	x	5
For flashing signals		x				1
In the automobile		x			x	2
Multiple reflection		x	x	x		3
The kaleidoscope		x		x		2
Thick plate-glass mirror		x				1
Terms used with curved mirrors	x	x	x	x	x	5
Convex	x	x	x	x	x	5
Concave	x	x	x	x	x	5
Radius of curvature	x	x	x		x	4
Center of curvature	x	x	x	x	x	5
Aperture		x				1
Vertex		x		x		2
Principal axis	x	x	x	x	x	5
Secondary axis	x	x			x	3
Normal		x		x		2
Focusing light waves	x	x		x	x	4
Definition of focus	x	x		x	x	4
Virtual focus	x	x			x	3
Focal length of the mirror	x	x	x	x	x	5
Principal focus	x	x	x	x	x	5
Converging rays	x	x	x	x		4
Diverging rays	x	x	x	x		4
55. Images of curved mirrors	x	x	x	x	x	5
Method of locating images in convex mirrors..................	x			x	x	3
Method of locating images in concave mirrors.................	x	x	x	x	x	5
An image without a screen			x			1
Images formed by concave mirrors	x	x	x	x	x	5
Object at infinite distance		x				1
Object at finite distance beyond center of curvature....	x	x	x	x	x	5
Object at center of curvature	x	x				2
Object between center of curvature and principal focus..	x	x	x	x	x	5
Object at principal focus		x		x		2
Object between principal focus...............and mirror	x	x	x	x	x	5
Images formed by convex mirrors	x	x	x	x	x	5
Virtual, erect, smaller than the object..................	x	x	x	x	x	5
Behind the mirror	x	x	x			3

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
55. (Continued)						
Nearer the mirror than is the object..................				x		1
Uses of the convex mirror		x	x	x	x	4
In amusement parks				x		1
In vehicles	x	x	x	x	x	5
Optical sighting gage				x		1
Uses of the concave mirror	x	x	x	x	x	5
Reflectors of light	x	x		x		3
Forming images		x		x		2
Shaving mirror		x	x	x		3
Dentist mirror		x	x			2
Headlights in vehicles	x	x	x	x	x	5
Reflecting telescope				x		1
Compound microscope				x		1
Searchlight		x	x		x	3
Spotlight		x		x		2
Physician's ophthalmoscope		x			x	2
Stage lighting				x		1
Spherical lighting and aberration..........................	x	x	x	x	x	5
Remedies for spherical aberration......................	x	x	x	x	x	5
Cut off outside rays	x	x		x		3
Use a parabolic mirror	x	x	x		x	4
Comparison of relative sizes of object and image...............	x	x		x	x	4
The mirror formula	x	x	x	x	x	5
56. Refraction of light waves	x	x	x	x	x	5
What is refraction?	x	x	x	x	x	5
Definition of refraction	x	x	x	x	x	5
Angle of refraction	x	x				2
Angle of deviation	x	x				2
What causes refraction?	x	x	x	x	x	5
Index of refraction	x	x	x	x	x	5
Deriving it from geometry	x	x	x	x	x	5
Uses: refractometer, food testing.....................		x				1
Laws of refraction	x	x	x	x	x	5
Tracing a ray light through a glass plate....................	x	x	x	x	x	5
Length of day increased by refraction.....................				x		1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
56. (Continued)						
Atmospheric refraction		x	x	x	x	4
Twinkling of stars				x		1
"Looming" phenomenon				x		1
Mirage				x		1
Meaning of "critical angle"	x	x	x	x	x	5
How total reflection can be made useful....................		x	x	x	x	4
In the diamond	x	x				2
Adding lead to glass		x				1
Right-angle prisms		x	x	x	x	4
Principle of the periscope		x	x	x		3
In the high-grade field glasses..................		x	x	x		3
Reflecting telescopes		x	x			2
Range finders on battle-ships and cameras........		x		x		2
Principle of the tur-ret range finder......				x		1
Refraction increases knowledge				x		1
57. Lenses and images	x	x	x	x	x	5
What lenses do for us		x		x		2
What is a lens?		x	x		x	3
Converging lens	x	x	x	x	x	5
Flat lenses		x	x			2
Meniscus lens		x	x	x		3
How lenses affect light	x	x				2
Definition of terms	x	x	x	x	x	5
Center of curvature	x	x		x		3
Principal axis	x	x		x	x	4
Secondary axis	x	x				2
Optical center	x	x	x	x		4
Principal focus	x	x	x	x	x	5
Principal focal length	x	x	x	x	x	5
Conjugate foci	x		x	x	x	4
Radius of curvature	x	x	x			3
How lenses form images	x	x	x	x	x	5
Differences between lenses and mirrors.................		x				1
Graphical construction of an image..	x	x	x		x	4
Change of wave front produced by a convex lens...............					x	1
58. Images of curved lenses	x	x	x	x	x	5
Images formed by convex lenses	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
58. (Continued)						
Object at infinite distance	x	x		x	x	4
Used to find the focal length....................		x	x	x		3
Object distant from lens more than twice focal length.....	x	x		x	x	4
Lenses of the eye		x				1
Camera		x				1
Telescope		x				1
Object distant twice focal length.....................	x	x		x	x	4
Field telescope		x				1
Object distant more than once and less than twice the focal length.....................	x	x	x	x		4
Compound microscope		x				1
Optical lantern		x				1
Motion projector		x				1
Object at principal focus		x		x	x	3
Lighthouse		x				1
Searchlight		x				1
Object distant from lens less than one focal length.........	x	x	x	x	x	5
Simple magnifier	x	x		x	x	4
Eyepieces of microscopes and telescopes...........	x	x		x		3
Images formed by concave lenses	x	x	x	x	x	5
Virtual	x	x	x	x	x	5
Erect		x	x	x	x	4
Same side of lens as the object.........................	x			x		2
Smaller than the object		x	x	x	x	4
Spherical aberration for lenses	x	x		x	x	4
Diaphragm used to correct it	x	x		x	x	4
Ground lenses used to prevent it...........................	x	x		x		3
Finding the relative sizes of image and object...............	x	x	x	x	x	5
Relation of distance of object and image to focal length......	x	x	x	x	x	5
59. Structure of the human eye	x	x	x	x	x	5
Whitecoat or cornea	x	x	x	x	x	5
Middle coat or vitreous humor	x	x	x	x	x	5
Inner coat or retina	x	x	x	x	x	5
Crystalline lens	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
59. (Continued)						
Iris	x	x	x	x	x	5
Pupil	x	x		x		3
Principle of stereoscopic vision				x		1
How the eye forms images	x	x			x	3
Power of accomodation		x			x	2
Eye is self-focusing	x	x			x	3
Nearest distance for distinct vision	x	x			x	3
Correcting defects of the eye	x	x	x	x	x	5
Nearsightedness	x	x	x	x	x	5
Use of concave lenses	x	x	x	x	x	5
Farsightedness	x	x	x	x	x	5
Use of convex lenses	x	x	x	x	x	5
Use of bi-focals for presbyopia		x	x		x	3
Astigmatism	x	x	x	x	x	5
Use of cylindrical lenses					x	1
Use of ground lenses	x	x	x			3
Why meniscus or spectacle lenses are used	x	x		x		3
Wide range of vision	x	x		x		3
Conformity to the shape of the eyeball		x		x		2
How to judge size	x	x		x		3
Size of the visual angle	x	x		x		3
How to estimate distance	x	x		x		3
Importance of binocular vision	x	x		x	x	4
Using range finders aboard battleships		x		x		2
Comparison of the camera and the eye	x	x	x			3
Optical illusions and camouflage		x				1
Uses of the anastigmat and rectilinear lenses		x				1
Effective aperture of a lens		x				1
Relative aperture of a lens		x				1
60. Optical instruments	x	x	x	x	x	5
Simple magnifier	x	x	x	x	x	5
Approximate magnifying power		x			x	2
Construction of the compound microscope	x	x	x		x	4

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
60. (Continued)						
Objective lens	x	x	x		x	4
Magnifying power	x	x			x	3
Eyepiece	x	x	x		x	4
Magnifying power	x	x			x	3
Total magnification of eyepiece and objective.........	x	x			x	3
Galileo's first telescope				x		1
Kinds of astronomical telescopes	x	x	x	x	x	5
Refracting telescope	x	x	x	x	x	5
Reflecting telescope	x	x	x	x	x	5
Construction of the telescope	x	x	x		x	4
Construction of opera glasses	x	x	x		x	4
Magnification	x		x			2
The prism binocular	x	x	x	x	x	5
Principle of the picture projector.........................	x	x	x	x	x	5
Principle that makes motion pictures possible..............	x	x	x	x	x	5
Duration of vision	x	x	x	x		4
Projecting motion pictures	x	x	x	x	x	5
Adding sound to motion pictures...................	x	x	x	x	x	5
Using lampshades to modify illumination....................		x				1
Direct system	x	x				2
Indirect system	x	x			x	3
Semi-indirect system	x	x				2
Diffusion	x	x	x			3
Floodlighting		x				1
Fluorescent lamp	x	x		x		3
How neon gas is used in lighting	x	x				2
61. Color light	x	x	x	x	x	5
Cause of dispersion of light	x	x	x	x	x	5
Solar spectrum	x	x	x	x	x	5
Polychromatic light	x	x	x	x	x	5
Monochromatic light		x	x			2
Limited range of the eye	x					1
Determining the color of bodies	x	x	x	x	x	5
Formula for vibration rate of light.....................		x				1
Correlation of color to wave length.........................		x		x	x	3
Determining the color of objects.....................	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
61. (Continued)						
Artificial light		x				1
Color of transparent objects..................	x	x	x	x	x	5
Synthesis of white light	x	x	x	x	x	5
Few pure colors				x		1
Some lights deceive	x			x		2
Benjamin Franklin's views on light........................				x		1
Blue sky and sunset				x		1
How colors are named: tint, shade, warm colors, cool colors				x		1
Color harmony				x		1
Complementary colors	x	x	x	x	x	5
Primary colors	x	x		x		3
Newton disk	x		x		x	3
Von Nardoff's color apparatus		x		x		2
Young-Helmholtz color theory		x		x	x	3
Meaning of color blindness	x	x		x	x	4
What is retinal fatigue?		x				1
Result of mixing pigments	x	x	x	x	x	5
Three-color printing	x	x	x	x	x	5
Kinds of spectra	x	x	x	x	x	5
Continuous spectra	x	x		x	x	4
Discontinuous or bright-line spectra.....................	x	x	x	x	x	5
Absorption, or dark-line, spectra.....................	x	x	x	x	x	5
Meaning of Fraunhofer lines....................	x	x	x	x	x	5
Chromatic aberration	x	x	x	x	x	5
Definition of chromatic aberration....................	x	x		x		3
Achromatic lens used to remedy it................	x	x	x	x	x	5
Interference of light	x	x	x	x	x	5
What is diffraction?	x	x			x	3
Diffraction grating	x	x				2
62. Principle of the spectroscope:	x	x		x	x	4
collimator, equal-angled prism, telescope..........................	x	x	x	x	x	5
The spectroscope and scientific knowledge.........................	x		x	x	x	4
Ultraviolet rays	x	x	x		x	4
Causes sunburn	x					1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
62. (Continued)						
Treatment of certain ailments....................					x	1
Infrared rays	x		x		x	3
Beyond the range of visibility of the eye........	x					1
Detected with a spectroscope....................	x					1
Calculating the velocity of moving stars.................	x					1
Direct-vision spectroscope					x	1
Meaning of spectrum analysis	x	x			x	3
Analysis of compounds in testing for elements........		x				1
Discovery of caesium and rubidium......................		x				1
Discovery of helium		x				1
Explanation of the rainbow	x	x	x	x		4
63. Polarized light	x	x	x	x	x	5
What is polarized light?	x	x	x	x	x	5
Use of tourmaline crystals	x	x		x	x	4
What is polaroid?				x	x	2
The polariscope		x		x		2
Polarizer		x	x	x		3
Analyzer		x	x	x		3
Use in sugar refineries		x		x	x	3
The saccharimeter		x			x	2
Dextro-rotatory substance		x		x		2
Levo-rotatory substance		x		x		2
Uses of polarized light	x	x	x	x	x	5
Strains in a material are shown.......................	x	x			x	3
Learning the identity of tiny crystals.................		x				1
Polaroid glasses	x	x	x	x	x	5
Polaroid headlight lenses	x	x	x	x	x	5
Detecting certain minerals	x				x	2
How engineers use polarized light......................				x	x	2
Testing building materials		x		x	x	3
64. The camera	x	x	x	x	x	5
Essentials parts of a folding camera........................	x	x	x	x	x	5
Diaphragm	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
64. (Continued)						
Depth of field				x		1
Shutter	x	x	x	x	x	5
Spring-actuated shutter				x		1
Leaf-type shutter				x		1
Focal plane shutter				x		1
Lens speed				x		1
Lens ratings				x		1
Principle of the pinhole camera......................	x	x	x	x	x	5
Films				x		1
Roll film; film pack				x		1
Processing				x		1
Use of the developer				x	x	2
Use of the fixer or hypo				x		1
Fine-grain film				x		1
The negative			x	x		2
Making a print			x	x		2
Light and color				x		1
Film speed				x		1
Filters: photographic, orthochromatic, and panchromatic films; cloud pictures; filter factor..............				x		1
What size camera should you buy?.......................				x		1
65. Photography		x		x		2
What is photography?		x		x		2
Improvement of photography		x		x		2
Lighting for photography				x		1
Exposure meters				x		1
Indoor photography: photoflash and photoflood bulbs...........				x		1
The darkroom				x		1
Photographic enlarging				x		1
Infrared photography		x		x		2
Color photography		x		x		2
The color film	x	x	x	x	x	5
Layers in color film				x		1
Kodachrome process		x		x	x	3
Color prints on paper				x		1
Technicolor				x		1
Fun with your camera: photographic ghost; the silhouette..				x		1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
65. (Continued)						
Aerial photography	x					1
Oblique photograph	x					1
Vertical photograph	x					1
Cameras used in aerial photography..................	x					1
Single lens camera	x					1
Multiple lens camera	x					1
Camera sight or view finder	x					1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
66. Nature of magnetism	x	x	x	x	x	5
Why study magnetism?				x	x	2
Magnetism and scientific knowledge..........................	x	x				2
Where natural magnets are found	x	x	x	x	x	5
In Magnesia, Asia Minor	x	x	x	x	x	5
Discovered by the Greeks, called "magnetite"..........	x	x	x		x	4
In the Adirondacks; known as "natural magnets"...........		x				1
Found in eastern United States, parts of Norway and Sweden......................				x	x	2
How we can make a magnet	x	x	x	x		4
Magnetic materials: iron, steel, nickel, cobalt, some alloys....	x	x	x	x	x	5
Non-magnetic materials: wood, copper, glass, aluminum, brass.	x	x		x		3
Property of diamagnetism: bismuth, zinc, antimony...........	x	x				2
Magnetic screening	x				x	2
Meaning of polarity		x		x	x	3
Law of magnets	x	x	x	x	x	5
How to make a compass				x	x	2
Test for magnetism		x	x	x		3
Use of the ordinary magnetic compass......................	x	x	x		x	4
To show directions	x	x	x			3
How the airplane compass works......................	x					1
Temporary and permanent magnets	x	x		x	x	4
Temporary magnet	x	x		x	x	4
Core has little retentivity....................	x	x				2
Retains a little residual magnetism................		x				1
Permalloy loses its magnetism easily............	x	x	x		x	4
Demagnetizing steel	x	x		x	x	4
Heating a magnet destroys its magnetism...............	x	x		x	x	4
Tapping or jarring	x	x	x	x	x	5
Dropping		x		x		2
Pounding	x	x	x			3
Twisting					x	1
Use of alternating current		x				1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
66. (Continued)						
Meaning of magnetizing by induction.....	x	x	x	x	x	5
Definition of induced magnetism.....	x	x	x		x	4
What are lines of force?	x	x	x	x	x	5
Mayer's floating magnet	x	x				2
What is a magnetic field?	x	x	x	x	x	5
Field of unit strength is called a maxwell.....	x	x				2
Magnetic field of unit intensity is called a gauss.....		x				1
Mapping a magnetic field	x	x			x	3
Properties of lines of force	x	x	x	x	x	5
Closed curves extending from north-to-south-seeking pole.	x	x	x	x	x	5
Do not cross one another		x		x	x	3
Concentrated at the poles	x	x	x	x		4
Farther apart at the center of magnet.....				x		1
What is magnetic transparency?		x	x	x		3
What is permeability?	x	x	x	x	x	5
What is reluctance?					x	1
Importance of the shape of a magnet.....	x	x	x			3
Horseshoe magnet	x	x	x	x	x	5
Theory of magnetism	x	x	x	x	x	5
Facts supporting the theory of magnetism.....	x	x		x		3
67. Terrestial magnetism	x	x	x	x	x	5
Meaning of terrestial magnetism	x	x		x		3
The earth is a magnet	x	x	x	x	x	5
Gilbert's "terrella"		x	x		x	3
Earth's lines of force are magnetic meridians.....		x		x		2
What is magnetic declination?	x	x	x	x	x	5
Homemade dipping needle	x		x	x	x	4
Angle of declination	x	x		x		3
Line of zero declination	x	x				2
West declination	x	x	x	x		4
East declination	x	x	x	x		4
Agonic line	x	x	x	x		4
Isogonic line	x	x	x	x		4
Pilots of airplanes concerned with declinations.....	x					1
Method for plotting a true course on a map.....	x					1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
67. (Continued)						
What is magnetic inclination or dip?........................	x	x	x	x	x	5
Use of the dipping needle	x	x	x			3
Magnetic equator is an aclinic line.....................		x		x		2
Isoclinic lines		x		x		2
Showing the inductive action of the earth.....................	x	x	x	x		4
Finding the compass course of an airplane....................	x					1
Shortcomings of the compass		x		x	x	3
Powerful permanent magnets				x		1
Magnetic checkers				x		1
Inside a thermostat				x		1
68. Static electricity: what it is	x	x	x	x	x	5
Static electricity was known to the ancients..................	x	x	x		x	4
In 600 B.C. the Greek philosopher Thales discovered it	x	x	x	x	x	5
In 1600 A.D. William Gilbert distinguished between magnetism and electricity........	x	x			x	3
In 1752 Benjamin Franklin's experiment of flying a kite in a thunderstorm..........	x	x	x	x	x	5
In 1772 Otto von Guericke constructed a crude electrical machine for producing static electricity....		x				1
Electricity can be produced by friction......................	x	x	x	x	x	5
Use of a pith-ball electroscope.....................	x	x	x	x	x	5
Kinds of electricity: positive, negative....................	x	x	x	x	x	5
Law of electrification	x	x	x	x	x	5
Theory of electricity	x	x	x	x	x	5
Franklin's theory	x	x		x		
Electron theory	x	x	x	x	x	5
How the theory applies		x		x		2
Chemically		x				1
Electrically		x		x		2
Electrons liberated by rubbing together two dissimilar substances......................	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
68. (Continued)						
Experiment showing electrons liberated by chemical action			x	x		2
Detection of electrical condition of a body.................	x	x	x	x	x	5
What is an electroscope?	x	x	x	x	x	5
Use of the electroscope: to detect the presence of an electric charge; to determine the sign of the charge......	x	x	x	x	x	5
To measure its intensity	x					1
In the study of radioactive material....................	x					1
How electricity is conducted through solids.................	x	x	x	x	x	5
Producing electrification: by contact, induction.......	x	x	x	x	x	5
Grounding				x		1
Charging an electroscope by induction..................	x	x	x	x	x	5
Nonconductors	x	x	x	x	x	5
Conductors	x	x	x	x	x	5
Semi-conductors		x		x	x	3
Where the electric charge resides.....................	x	x	x		x	4
Faraday's experiment		x				1
Importance of the shape of the conductor..............	x	x	x			3
Electrical density is greatest at the point of greatest curvature.......	x	x		x	x	4
Effect of discharge from points......................	x	x	x	x		4
Producing an "electrical wind"..................	x	x	x			3
Pointed conductor loses its charge rapidly.......		x			x	2
How electrical quantities are measured......................	x	x	x	x	x	5
Electrical pressure	x	x	x	x	x	5
Amount of current directly proportional to the effective pressure.......	x	x		x		3
Definition of the volt	x	x	x	x	x	5
Definition of the ampere	x	x	x	x	x	5
Definition of the ohm	x	x	x	x	x	5
Electro-motive force	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	Book					
	A	B	C	D	E	N
68. (Continued)						
Effective pressure is known as the difference of potential.............	x	x		x		3
Elementary charge	x					1
Electrostatic unit	x					1
Coulomb	x	x	x	x	x	5
Continuous currents	x					1
What may happen when we build up pressure?..................		x				1
What is lightning?	x	x	x	x	x	5
Lightning rods furnish protection.....................	x	x	x	x	x	5
Precautions taken in installing rods............	x	x		x	x	4
Danger from lightning	x		x	x		3
Value of lightning				x		1
Man-made lightning				x	x	2
Van De Graaf machine for generating static electricity....................	x	x	x	x	x	5
What is a condenser?	x	x	x	x	x	5
Hydraulic analogy of a condenser....................					x	1
Definition of a condenser	x	x	x	x	x	5
Capacitance of a condenser	x	x	x	x	x	5
Increases with size of plates....................	x	x	x	x	x	5
Increases as distance between plates decreases...	x	x	x	x	x	5
Depends upon the insulator or dielectric........	x	x		x	x	4
How a condenser works	x	x	x	x	x	5
Capacitance, dimensions, and charge: farad, micro-farad..	x	x				2
How commercial condensers are constructed..................	x	x	x	x	x	5
The Leyden jar	x	x	x	x	x	5
How to discharge it				x		1
Variable condensers	x	x		x	x	4
Fixed condensers		x		x		2
What is an electrophorus?	x	x	x	x	x	5
How induction machines work	x	x		x	x	4
Wimshurst electrical machine	x	x		x	x	4

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
68. (Continued)						
Electrostatic generator	x			x	x	3
Uses of induction machines	x	x		x	x	4
For demonstration purposes in the laboratory....	x	x		x	x	4
For operating X-ray tubes		x				1
The Cottrell is used to precipitate dust and smoke		x				1
Comparison of magnetism and electricity: points of resemblance; chief differences......		x				1
69. Current electricity - Voltaic cells	x	x	x	x	x	5
Difference between current and static electricity.............		x				1
Water analogy of electrical pressure........................	x	x	x	x	x	5
Speed of current flow	x			x		2
What is a voltaic cell?	x	x	x	x	x	5
Some electrical terms in common use...........................	x	x	x	x	x	5
Some labeled diagrams in common use...........................		x				1
Theory of action in a simple voltaic cell......................	x	x	x	x		4
The cell in use	x	x	x			3
Theory apparently incomplete			x			1
Defects of voltaic cells	x	x	x	x		4
Local action	x	x	x	x		4
Polarization	x	x	x	x	x	5
Cells on open and closed circuits..................		x	x			2
Preventing or remedying polarization.........................		x	x	x		3
Mechanical		x	x	x		3
Chemical	x	x	x	x	x	5
By construction		x				1
Terminal voltage of the cell				x	x	2
Quickly made cells				x		1
Construction of the dry cell	x	x	x	x	x	5
The Weston normal cell	x					1
Leclanche cells				x		1
Daniel cells or gravity cells		x		x		2
Values of the electrical units: volt, ampere, ohm..............	x	x	x		x	4
What is Ohm's law?	x	x	x	x	x	5
Testing and using Ohm's law	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
69. (Continued)						
Laws of resistance	x	x	x	x	x	5
Law of lengths	x	x	x	x	x	5
Law of diameters	x	x	x	x	x	5
Effect of temperature	x	x	x	x	x	5
Resistance depends upon the material....................	x	x	x	x		4
Resistivity, or specific resistance................	x	x	x	x	x	5
Comparative resistance of materials................				x		1
Peculiar effects of temperature on resistance..........				x	x	2
Superconductivity				x	x	2
Materials used and E.M.F.	x	x		x		3
Size of cell and its E.M.F.	x					1
Measuring the resistance of a voltaic cell..............	x	x				2
Voltaic cells vary in resistance........................	x	x		x		3
Cells connected in series	x	x	x	x	x	5
Cells connected in parallel	x	x	x	x	x	5
Best arrangement of cells		x		x	x	3
70. Magnetic effects of electricity	x	x	x	x	x	5
Oersted's discovery	x	x		x	x	4
Finding the direction of current flow......................	x		x	x	x	4
Right-hand rule	x	x	x	x	x	5
What is the helix or solenoid?	x	x	x			3
Magnetic field about a solenoid	x				x	2
The electro-magnet	x	x	x	x	x	5
How to make an electro-magnet.........................	x	x	x	x		4
Increasing the strength of an electro-magnet...........	x	x	x	x	x	5
Polarity of an electro-magnet	x	x		x	x	4
Uses for electro-magnets	x	x		x		3
What an electric bell consists of: how it works...............	x	x	x	x	x	5
How bells are wired		x	x			2
The electric telegraph	x	x	x	x	x	5
The telegraph key is a circuit closer.................	x	x	x	x	x	5
The sounder gives the signal	x	x	x	x	x	5
What is the Morse code?		x	x			2

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
70. (Continued)						
Use of the relay	x	x	x	x	x	5
Connecting telegraph instruments........................		x		x		2
Modern telegraph development				x		1
What is the teletype system?	x	x				1
Uses of the teletype system		x				1
71. Chemical effects of electricity	x	x	x	x	x	5
Liquids as conductors	x			x	x	3
Testing electrolytes				x	x	2
What is electrolysis?	x	x			x	3
Definition of electrolysis	x	x	x		x	4
Parts of an electrolytic cell	x	x	x	x	x	5
Electrolysis of sulfuric acid	x	x		x		3
Electrolysis of hydrogen chloride...........................					x	1
How to electrolyze water	x	x	x	x	x	5
Electroplating	x	x	x	x	x	5
Chromium plating	x					1
How electrotypes are made	x	x	x		x	4
How metals are extracted		x				1
Hall process - Electro- metallurgy......................		x				1
Refining of metals	x	x			x	3
Electrochemical equivalents of metals..........................	x				x	2
Producing aluminum				x		1
Laws of electrolysis	x	x				2
Principle of the storage cell: its construction...............	x	x	x	x	x	5
How the lead storage cell works......................	x	x	x	x	x	5
Construction of the Edison storage battery.............	x	x		x		3
Advantages and disadvantages of the storage cell.........		x				1
Rating of storage batteries	x				x	2
Care of the storage battery	x	x	x			3
Uses of storage cells		x			x	2
72. Heating and lighting effects of electricity.......................	x	x	x	x	x	5
Electric current causes heat	x	x	x	x	x	5
Induction heating		x		x		2
Dielectric heating				x		1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
72. (Continued)						
Joule's laws	x	x	x	x		4
Practical applications of electrical heating................	x	x	x	x		4
Electric ranges				x		1
Thermocouple, or electric thermometer................	x			x		2
Use of the thermocouple: the pyrometer............	x			x		2
How wires may be overloaded		x	x	x		3
By putting too many appliances on one circuit........		x		x		2
By a short circuit	x	x	x		x	4
Fuses are a protection	x	x	x	x	x	5
Kerosene lamp				x		1
The incandescent lamp	x	x	x	x	x	5
Tungsten lamps are better than carbon lamps.................	x	x	x	x	x	5
Electric lamp circuits			x			1
How the electric arc lamp works	x	x	x	x	x	5
Construction of vapor lamps	x	x	x	x	x	5
Mercury vapor lamp	x	x	x	x	x	5
Sun lamp	x			x	x	3
Sodium-vapor lamp	x	x	x	x	x	5
Neon lamp	x	x		x	x	4
Electric furnaces give high temperature....................		x			x	2
Resistance furnaces		x			x	2
Arc type furnaces		x				1
Fluorescent lamps: their operation.........................	x	x		x		3
Daylight in the house				x		1
73. Electrical measuring instruments	x	x	x	x	x	5
The galvanoscope	x	x		x		3
Purpose of the galvanometer	x	x	x	x	x	5
Weston (movable needle) galvanometer..................	x	x		x		3
D'Arsonval (movable-coil) galvanometer................	x	x	x	x	x	5
How the voltmeter works	x	x	x	x	x	5
How the ammeter is used	x	x	x	x	x	5
Reflecting galvanometer		x		x		2
Advantages of the volt-ammeter........................				x		1
What is a rheostat?		x		x		2
Care and repair of home electrical appliances.............				x		1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
74. Series and parallel wiring	x	x	x	x	x	5
Potential drop along a conductor..........................	x	x		x	x	4
Measuring drop in potential		x		x	x	3
Results of series wiring	x	x	x	x	x	5
Defects of series wiring				x		1
Results of parallel wiring	x	x	x	x	x	5
Total resistance of parallel conductors....................	x	x	x	x	x	5
Proportion of current through each shunt...................		x		x		2
Why parallel wiring is so largely used................		x				1
75. Electric power and energy	x	x	x	x	x	5
What is electric power?	x	x			x	3
Electrical energy and heat	x	x	x	x	x	5
Electric calorimeter	x				x	2
Commercial unit of electrical energy..................	x	x	x	x	x	5
The watt-hour meter	x	x	x	x	x	5
How the electric power is calculated........................	x		x	x	x	4
76. Measurement of resistance	x	x	x		x	4
Voltmeter-ammeter method	x	x	x		x	4
Substitution method		x	x			2
Wheatstone bridge method: uses	x	x		x		3
Use of resistance boxes	x	x		x		3
Measurement of temperature in aviation................	x					1
Testing the exhaust gas of airplane engines...........	x					1
Importance of measuring instruments.........................				x		1
Instrument manufacture demands dexterity.....................				x		1
77. How a current is produced by induction............................	x	x	x	x	x	5
Principle of induction	x	x	x	x	x	5
Current may be induced in a moving conductor.................	x	x	x	x	x	5
Direction taken by the induced current........................	x	x		x	x	4
Fleming's right-hand rule	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
77. (Continued)						
Hall rule		x				1
Meaning of Lenz's law	x	x		x	x	4
Strength of the induced e.m.f.	x	x		x		3
Inducing one current by another				x	x	2
78. Dynamos and alternators	x	x	x	x	x	5
Fundamental principle of generators..........................	x	x	x	x	x	5
Inducing current in a revolving loop..........................	x	x		x	x	4
Taking current from the armature: slip rings, brushes......	x	x	x	x	x	5
What is a magneto?	x	x				2
How the alternating-current dynamo works.....................	x	x	x	x	x	5
Field magnet	x	x	x	x		4
Armature	x	x	x		x	4
Slip-rings and brushes	x	x	x	x	x	5
Single-phase and polyphase dynamos....................	x			x	x	3
Uses of alternating current	x	x			x	3
Direct-current dynamo	x	x	x	x	x	5
How a direct current is produced.......................	x	x	x	x	x	5
Voltage of a generator	x					1
Sources of energy in the generator..........................		x			x	2
Importance of the generator	x		x		x	3
79. Armatures and magnetic fields	x	x	x	x	x	5
Types of armatures	x	x				2
Drum-wound armature	x	x	x			3
Eddy currents	x	x				2
Ring-wound armature		x				1
How the field magnet is magnetized: in the dynamo; in the alternator....................		x	x			2
Self-excited machines: series, shunt, compound................	x	x				2
Comparison of alternating and direct current.................	x	x		x		3
Comparison of alternators and dynamos........................		x				1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
80. The electric motor	x	x	x	x	x	5
How the electric motor works	x	x	x	x	x	5
What makes a motor run?	x	x		x	x	4
Fleming's left-hand rule	x	x			x	3
Torque of a motor armature	x	x			x	3
Use of series-wound D.C. motor	x	x	x	x	x	5
Use of shunt motors		x	x	x	x	4
How alternating-current motors work..........................	x	x		x	x	4
Induction motor	x	x		x	x	4
Stator produced a rotating field...............	x	x		x	x	4
Rotor	x	x		x	x	4
Two-phase motor	x					1
Three-phase induction motor......................	x					1
Single-phase motor	x				x	2
A-C electric clocks				x		1
Back e.m.f. of a motor	x	x		x	x	4
Starting box of a motor	x	x		x		3
Efficiency of a motor	x				x	2
What are circuit breakers?		x		x	x	3
Underload circuit breaker		x				1
Overload circuit breaker	x	x				2
81. Electro-magnetic induction	x	x	x	x	x	5
Induction caused by varying a magnetic field.................	x	x	x	x	x	5
Battery current produces an induced current.............	x	x			x	3
Purposes of the induction coil.........................	x	x	x	x		4
Uses of the induction coil....................		x		x	x	3
82. Voltage transformer and power transmission......................	x	x	x	x	x	5
Principle of the voltage transformer........................	x	x	x	x	x	5
How transformers are made	x		x			2
Step-down transformer	x	x	x	x	x	5
Step-up transformer	x	x	x	x	x	5
Uses of the step-down transformers.....................	x			x		2
Alternating current is used in power transmission............	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
82. (Continued)						
High-voltage and low power loss........................	x	x	x	x	x	5
Relation of primary and secondary current..............	x		x			2
Uses of eddy currents in damping				x	x	2
Types of transformers: core, shell..........................	x					1
Distributor transformer					x	1
Uses of transformers	x	x	x	x	x	5
Efficiency of a transformer		x			x	2
Long-distance transmission of power.........................		x			x	2
83. The telephone	x	x	x	x	x	5
Principle of the telephone	x	x	x	x	x	5
How the transmitter works	x	x	x	x	x	5
Construction of the audiphone		x				1
What is self-induction?	x	x		x	x	4
The telephone circuit	x		x		x	3
Sound on a wire				x		1
84. Alternating current power	x	x	x	x	x	5
Calculating alternating current power.........................	x	x				2
Relation between maximum and effective A.C....................	x					1
Measuring instruments for A.C.	x					1
Repulsion type of ammeter and voltmeter...............	x					1
Hot-wire ammeter	x			x		2
The wattmeter	x	x	x	x	x	5
Power factor	x	x				2
Explanation of reactance	x	x				2
Meaning of impedance	x	x		x	x	4
What is a choke coil?		x			x	2
Induced E.M.F. versus applied E.M.F..........................	x					1
Condenser in an alternating-current circuit................					x	1
85. Current rectifiers	x	x		x	x	4
What is a rectifier?	x					1
Changing alternating to direct current.......................	x	x	x	x	x	5
Motor generator	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
85. (Continued)						
Rotary converter	x	x		x		3
Tungar rectifier	x	x		x		3
Cuprous-oxide rectifier		x		x	x	3
The audion tube or bulb		x		x		2
Electrolytic rectifier	x					1
86. Cathode rays	x	x	x	x	x	5
Electrical discharge can take place in vacuums..............	x	x	x	x	x	5
The Geissler tube	x	x				2
What are cathode rays?	x	x	x		x	4
Heating effects	x	x			x	3
Fluorescent effect	x		x	x	x	4
Shadow which they produce	x	x				2
Mechanical effects	x	x				2
Nature of cathode rays	x	x		x	x	4
What is the Coolidge tube?	x	x	x		x	4
What is the oscillograph tube?		x				1
Uses of the oscillograph		x				1
87. X-rays	x	x	x	x	x	5
Nature of X-rays		x			x	2
What are X-rays?	x	x	x			3
Production of X-rays	x					1
Uses of X-rays	x	x	x	x		4
What is a fluoroscope?	x	x				2
X-ray tubes	x	x	x			3
High voltage X-ray tubes	x					1
88. Radio	x	x	x	x	x	5
Inventor of the radio	x	x			x	3
Marconi's first radio receiver	x					1
Joseph Henry, a forerunner of radio...........................	x				x	2
Meaning of resonance between electric waves..................	x				x	2
Determining the "pitch" of electric waves.....................	x					1
Different types of ether waves: light, radio, heat, ultra-violet	x	x	x	x	x	5
X-rays	x	x	x	x	x	5
Cosmic rays	x	x		x	x	4
Velocity and frequency of radio waves.........................	x	x	x	x	x	5
Generating radio waves		x		x	x	3

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
88. (Continued)						
Low frequency radio waves				x		1
The three-electrode vacuum tube	x	x		x	x	4
How the audion tube acts as a detector......................	x	x		x	x	4
Putting voice on the air	x	x	x	x	x	5
Oscillator	x	x		x	x	4
Modulator	x	x		x	x	4
How the audion tube is used to amplify through its regenerative effect..........	x			x	x	3
The aircraft telephone transmitter.......................	x					1
Frequency modulation	x					1
Aircraft telephone receivers	x					1
How a radio set can work on the A-C 115-volt house current.....	x					1
Power supply for aircraft transmitters and receivers..........	x					1
How radio waves are received	x	x	x	x	x	5
The coherer	x	x				2
Crystal detectors	x	x			x	3
The audion tube	x	x		x	x	4
Radio aerials or antennas				x	x	2
The radio telephone		x				1
Uses of the photo-electric cell	x	x	x	x		4
89. Construction of a standard receiving set...........................	x	x		x	x	4
The filament circuit	x	x	x	x	x	5
The plate circuit	x	x	x	x	x	5
The grid circuit	x	x	x	x	x	5
Effect of grid condenser	x		x	x	x	4
Grid leak	x	x		x		3
Grid voltage and plate current	x			x	x	3
Superheterodyne circuits	x			x		2
Principle of tuning	x	x		x		3
Additional vacuum tubes produce amplification.................	x	x		x	x	4
Alternating current is used in receiving sets..................	x	x	x	x	x	5
What is wired radio?		x				1
How the radio compass works	x	x				2
Construction of the microphone		x				1
Granular carbon type of transmitter................		x				1

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
89. (Continued)						
Condenser microphone		x				1
Structure of the loud-speaker	x	x		x	x	4
Newer types of audion tubes have been developed...........		x				1
All metal-tubes		x				1
Screen-grid tube		x			x	2
Pentode tube		x		x	x	3
90. How television has been made possible............................	x	x	x	x		4
Difficulties to be mastered	x		x			2
The electric eye: transmission	x	x	x	x		4
The early receiver	x	x				2
The neon tube	x					1
The modern transmitter	x	x		x		3
Picture transformed into electric impulses by the iconoscope....................	x	x		x		3
Electric impulses transformed into picture by the kinescope	x	x		x		3
Sending pictures by wire	x		x			2
The electron microscope	x			x		2
The modern receiver		x		x		2
Electron gun				x		1
Scanning is done inside the iconoscope..................				x		1
Interlaced scanning				x		1
Picture detail				x		1
Blanking of the beam				x		1
Television range				x		1
Television antennas				x		1
The picture channel				x		1
Synchronizing separator				x		1
Receiver controls				x		1
Interference				x		1
Color television				x		1
Television receiving screens				x		1
Television networks				x		1
91. Radio-activity	x	x	x		x	4
What is radio-activity?	x	x	x		x	4
How radium was discovered	x	x			x	3
What is radium and what does it do?..........................	x	x			x	3

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
91. (Continued)						
Affects a photographic plate		x	x		x	3
Discharges an electroscope		x			x	2
Produces fluorescence with certain salts................	x	x			x	3
Is active chemically		x			x	2
Physiological effects		x				1
Glows in the dark		x				1
Gives off tremendous heat		x			x	2
Is rare and expensive		x	x			2
Used in the cure of cancer	x				x	2
Nature of Becquerel rays	x	x	x		x	4
What is the spinthariscope?		x				1
The radium atom disintegrates	x	x	x			3
Can atomic energy be utilized?		x		x		2
Construction of atom-smashing machines.......................	x	x			x	3
What cyclotrons accomplish		x			x	2
What are neutrons and positrons?	x	x	x		x	4
How a Wilson cloud chamber is used............................	x	x			x	3
Using radar		x		x		2
Artificial radio-activity					x	1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
92. The automobile	x	x	x	x	x	5
Transportation depends on the principles of physics..........	x	x	x			3
The automobile has three parts		x	x	x		3
Power plant	x	x	x	x		4
Chassis, or running gears		x	x	x		3
Body		x	x	x		3
Power plant has been improved		x				1
Importance of the cooling system..........................	x	x	x	x	x	5
How gasoline gets to the engine	x	x	x	x	x	5
Purpose of the carburetor	x	x	x	x		4
How the carburetor works	x	x	x	x	x	5
Purpose of the choke		x	x			2
The chassis		x		x		2
Plan of the drive mechanism		x		x		2
How the clutch works	x	x	x	x		4
The automobile brake drum	x	x	x			3
Hydraulic brake of an automobile.........................	x					1
How the liquid clutch works	x		x	x		3
Liquid coupling principle	x	x				2
Use of transmission gears	x	x	x	x		4
Synchro-mesh transmission	x	x	x	x		4
Constant mesh transmission				x		1
What is the differential?	x	x	x	x		4
Parts of the differential	x	x	x	x		4
How the differential functions......................	x	x	x	x		4
Parts of the ignition system	x	x	x	x	x	5
Body of the car must be strong		x		x		2
How modern warfare is changing the automobile.................		x				1
Why men make alloys		x				1
Safe driving of an automobile	x					1
Winter driving			x			1
Starting system of an automobile	x					1
Safety gasoline				x		1
Comfort on the road				x		1
Knee action				x		1
Steering				x		1
Wheel alignment				x		1
Tire balance				x		1
93. The airplane and its control	x	x	x	x	x	5
Forces affecting an airplane in flight.....................	x	x	x	x	x	5

TABLE I (CONTINUED)

Topics	A	B	C	D	E	N
	Book					
93. (Continued)						
Lift forces of an airplane	x	x	x	x	x	5
Chord of an airfoil	x					1
Calculating the lift on a wing........................	x		x			2
Lift forces affected by angle of attack..................	x	x	x			3
Lift forces affected by velocity......................	x	x		x	x	4
Lift forces affected by density......................	x	x				2
Lift forces affected by the size and contour of the wing	x	x		x		3
Overcoming the force of air resistance..................	x				x	2
Relation of thrust and drag	x		x		x	3
Principle of the airfoil	x	x	x	x		4
Power for an airplane wing	x					1
Meaning of the angle of incidence..........................		x				1
Air flow or streamlining	x	x	x	x		4
Stabilization and control of an airplane.......................	x	x		x		3
How the rudder and elevators work.......................		x	x	x		3
What the ailerons do		x	x	x		3
The fin and stabilizer		x	x	x		3
Longitudinal stability	x	x				2
Tail plane of an airplane	x	x				2
Down-wash of an airplane	x	x				2
Thrust of an airplane	x		x		x	3
Drag of an airplane	x		x		x	3
Lateral stability	x	x				2
Directional stability	x	x				2
How to identify planes	x	x				2
How airplanes are powered		x				1
The cyclone engine grows up		x				1
How the supercharger works		x				1
Classes of aircraft engines	x			x		2
Cooling systems of aircraft engines..........................	x	x				2
The cyclone engine grows up		x				1
How the airplane is flown			x			1
Important parts of an airplane engine.........................	x			x		2
Effect of motor torque			x			1

TABLE I (CONTINUED)

Topics	Book A	B	C	D	E	N
93. (Continued)						
The aircraft propeller	x		x			2
Feathering and windmilling of an airplane.............	x					1
Variable pitch propellers			x			1
Geared propellers			x			1
Methods used to make flying safe.........................		x				1
Factors of safety				x		1
Danger of flying over mountains		x				1
Terrain-clearance indicator		x				1
Airplane maneuvering			x			1
Steering in level flight			x			1
The take-off			x	x		2
Landing a plane			x			1
Designing an airplane	x					1
The wings of an airplane	x	x		x	x	4
The fuselage or hull	x					1
The landing gears	x					1
The control surfaces	x					1
The engine and propeller	x			x		2
Designing the glider	x			x		2
Heliocopters				x		1
Types of airplanes	x		x			2
Rocket and jet propulsion		x		x		2
Rocket bombs				x		1
Aerodynamics	x			x		2
Aerodynamics and the wind tunnel.......................	x			x		2
Bernoulli's old principle comes to life...............	x	x				2
Bernoulli's principle applied to the wing of an airplane.................	x	x				2
Airplane instruments depending upon air pressure..............	x		x			2
The altimeter	x					1
Rate-of-climb indicator	x					1
The speed indicator	x	x				2
Withstanding the stresses of an airplane.......................	x					1
Engine mount of an airplane	x					1
94. Radio in aviation	x		x			2
Flying by radio	x		x			2
Flying the radio beam	x					1

TABLE I (CONCLUDED)

Topics	Book A	B	C	D	E	N
94. (Continued)						
The radio direction finder of an airplane....................	x		x			2
Radio altimeter	x					1
Magnetic compass of an airplane	x					1
Bonding and shielding	x					1
Radio beacons	x		x			2
The A and N signals	x		x			2
Two-way radio	x		x			2
Radio in warfare			x			1
Government aid to navigation	x	x				2
Total frequency of occurrence of topics in each book	1291	1516	949	1216	1014	
Total frequency of occurrence of topics in all five textbooks						5986

Findings. The five textbooks analyzed contained a total of 1947 separate subject-matter topics. Only 94 of these were major topics; the remaining 1853 minor topics are subordinate to the 94 major topics. Of the 94 topics, which might logically be deemed major topics of the outline only, 78 appeared in all five textbooks, 9 in four, 2 in three, and the remaining 5 in two books.

The total frequency of occurrence of topics in any one book varied from 949 to 1516. The total frequency of occurrence of topics in all five books was 5986, an average of 1197.2 topics per book.

CHAPTER III

ASSIGNMENT OF THE MAJOR TOPICS TO PRINCIPLES

STATEMENT OF THE PROBLEM

The purpose of this part of the investigation is to assign to principles of physical science those topics, from the composite outline, which a study of might reasonably be expected to contribute to the development of an understanding of the principles.

TECHNIQUES EMPLOYED

Each of the 94 major topics related to the physical sciences was individually checked against the list of 272 physical principles developed by Wise. Whenever, in the opinion of the investigator, a discussion of a topic might reasonably be expected to include materials contributory to develop an understanding of a principle, the topic was assigned to that principle.

In some cases the same topics were assigned to several different principles. In order to conserve space, these principles were listed as a group and the topics that would have been assigned to each was placed after the last principle in the group.

No attempt was made to arrange the topics that were thus assigned in the best order for developing an understanding of that principle. Each principle was placed on a separate sheet of paper and all the topics assigned to it were listed below the principle. In order to check the defensibility of assignment of topics to the various principles, the completed list was submitted to the same three teachers of science who had checked the composite topical outline. If at least two of the three teachers agreed that a particular assignment should not be made, the topic was not assigned to the principle.

Whenever an assignment of a topic to a principle was questioned by any of the teachers, the investigator had a conference with the teacher and explained the basis on which that assignment was made. In every such case, with the exception of one assignment, the explanation given by the investigator was accepted by the teacher as justifying the assignment as originally made.

Table II, which follows, lists 171 principles of the physical sciences with their assigned topics. An attempt was made to place related principles together.

TABLE II

ASSIGNMENTS OF THE MAJOR TOPICS FOUND IN FIVE HIGH-SCHOOL TEXTBOOKS OF PHYSICS TO ONE HUNDRED SEVENTY-ONE PRINCIPLES OF PHYSICAL SCIENCE

Principles and Major Topics

PRINCIPLE

1. A body immersed or floating in a fluid is buoyed up by a force equal to the weight of the fluid displaced.

MAJOR TOPICS

*Liquid pressure and total force
Pressure on a confined liquid
Loss of weight of objects
Pressure of air
Expansibility and compressibility of gases
Compressed air
Molecular attraction
The airplane and its control

PRINCIPLE

2. The work obtained from a simple machine is always equal to the work put into it less the work expended in overcoming friction.

MAJOR TOPICS

Matter and energy
Principle of conservation of energy
Aid of machines in doing work
Mechanical advantages of machines
Friction
Efficiency of machines

*Table II is read thus: A discussion of any of the Major Topics such as "Liquid pressure and total force" can reasonably be expected to be contributory to the development of an understanding of the principle, "A body immersed or floating in a fluid..............displaced."

TABLE II (CONTINUED)

Principle and Major Topics

PRINCIPLE

3. Any homogeneous body of liquid, free to take its own position, will seek a position in which all exposed surfaces lie on the same horizontal plane.

MAJOR TOPICS

Pressure on a confined liquid
Wind, water, and weather
Behavior of matter
Molecular attraction

PRINCIPLE

4. A gas always tends to expand throughout the whole space available.

MAJOR TOPICS

Matter and energy
Expansibility and compressibility of gases
Behavior of matter
Molecular attraction
The nature of a solution
Heat and the state of matter
Study of meterology

PRINCIPLE

5. When one body exerts a force on a second body, the second body exerts an equal and opposite force on the first.

MAJOR TOPICS

Magnitude of two or more forces
Resolution of forces
Accelerated motion
Newton's law of motion
Curvilinear motion
The airplane and its control

TABLE II (CONTINUED)

Principle and Major Topics

PRINCIPLE

6. When there is a gain in mechanical advantage by using a simple machine, there is a loss in speed and vice versa.

MAJOR TOPICS

Principle of conservation of energy
Aid of machines in doing work
Mechanical advantages of machines
Compound machines
Friction
Efficiency of machines
Relation between heat and work

PRINCIPLE

7. The pressure at a point in any fluid is the same in all directions.

MAJOR TOPICS

Liquid pressure and total force
Pressure on a confined liquid
Pressure of air
Expansibility and compressibility of gases
Behavior of matter
Molecular attraction
The nature of a solution
Heat and the state of matter

PRINCIPLE

8. Any two bodies attract one another with a force which is directly proportional to the attracting masses and inversely proportional to the square of the distance between their centers of mass.

MAJOR TOPICS

Force of gravity
Newton's law of motion
Curvilinear motion

TABLE II (CONTINUED)

Principle and Major Topics
PRINCIPLE
9. In the lever the force times its distance from the fulcrum equals the weight times its distance from the fulcrum.
MAJOR TOPICS
Force of gravity
Magnitude of two or more forces
Resolution of forces
Aid of machines in doing work
Mechanical advantages of machines
Compound machines
PRINCIPLE
10. In the inclined plane, weight times height equals acting force times length, providing friction is neglected and the force is parallel to the plane.
MAJOR TOPICS
Magnitude of two or more forces
Mechanical advantages of machines
PRINCIPLE
11. The amount of momentum possessed by an object is proportional to its mass and to its velocity.
MAJOR TOPICS
Accelerated motion
Newton's laws of motion
Curvilinear motion
Principle of conservation of energy
PRINCIPLE
12. When pressure is applied to any area of a liquid in a closed container, it is transmitted in exactly the same intensity to every area of the container in contact with the liquid.

TABLE II (CONTINUED)

Principle and Major Topics
MAJOR TOPICS
Liquid pressure and total force Pressure on a confined liquid
PRINCIPLE
13. The energy which a body possesses on account of its motion is called kinetic energy and is proportional to its mass and the square of its velocity.
MAJOR TOPICS
Principle of conservation of energy Nature of heat
PRINCIPLE
14. Bodies in rotation tend to fly out in a straight line which is tangent to the arc of rotation.
15. Centrifugal force is directly proportional to the square of the velocity, to the mass, and inversely proportional to the radius of rotation.
16. A spinning body offers resistance to any force which changes the direction of the axis about which the body rotates.
MAJOR TOPICS
Newton's laws of motion Curvilinear motion
PRINCIPLE
17. The speed gained by a body with a constant acceleration is equal to the product of the acceleration and the time.
MAJOR TOPIC
Accelerated motion

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
18. At any point on the earth's surface, all bodies fall with a constant acceleration whcih is independent of the mass or size of the body if air resistance be neglected.
MAJOR TOPICS
Force of gravity Accelerated motion Newton's laws of motion
PRINCIPLE
19. When forces act in the same direction, the resultant is their algebraic sum.
MAJOR TOPICS
Magnitude of two or more forces Resolution of forces
PRINCIPLE
20. As the velocity of flow through a constricted area increases, the pressure diminishes.
MAJOR TOPICS
Curvilinear motion The airplane and its control
PRINCIPLE
21. The amount of heat developed in doing work against friction is proportional to the amount of work thus expended.
MAJOR TOPICS
Principle of conservation of energy Relation between heat and work

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE 22. All liquids are compressible but only to a slight degree. MAJOR TOPICS Pressure on a confined liquid Expansibility and compressibility of gases PRINCIPLE 23. Sliding friction is dependent upon the nature and condition of the rubbing surfaces, proportional to the force pressing the surfaces together and independent of the area of contact. MAJOR TOPICS Mechanical advantages of machines Compound machines Friction Efficiency of machines PRINCIPLE 24. The acceleration of a body is proportional to the resultant force acting on that body and is in the direction of that force. MAJOR TOPICS Force of gravity Accelerated motion Newton's laws of motion Curvilinear motion The airplane and its control PRINCIPLE 25. The distance a body travels, starting from rest with a constant acceleration, is one-half the acceleration times the square of the time.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

Force of gravity
Accelerated motion
Newton's laws of motion

PRINCIPLE

26. The distortion of an elastic body is proportional to the force applied provided the elastic limit is not exceeded.

MAJOR TOPIC

Molecular attraction

PRINCIPLE

27. When two forces act upon the same object, the resultant is the diagonal of a parallelogram whose sides represent the direction and magnitude of the two forces. A single force represented by the diagonal may be resolved into two forces represented by the sides of the parallelogram.

MAJOR TOPICS

Magnitude of two or more forces
Resolution of forces
The airplane and its control

PRINCIPLE

28. The rate of osmosis is directly proportional to the difference in concentration on opposite sides of the membrane.

MAJOR TOPIC

Behavior of matter

PRINCIPLE

29. Fluids have no elastic limit for compression.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

Pressure on a confined liquid
Molecular attraction

PRINCIPLE

30. The period of a pendulum swinging through short arcs is independent of the weight of the bob but varies directly as the square root of the length and inversely as the square root of the acceleration of gravity.

MAJOR TOPIC

Swinging pendulum

PRINCIPLE

31. When the resultant of all the forces acting on a body is zero, the body will stay at rest if at rest, or it will keep in uniform motion in a straight line if it is in motion.

MAJOR TOPICS

Force of gravity
Magnitude of two or more forces
Accelerated motion
Newton's laws of motion
Curvilinear motion

PRINCIPLE

32. Orderly arrangement of molecules, atoms, or ions in crystals gives the crystals regular form.

MAJOR TOPIC

Nature of a solution

PRINCIPLE

33. Fluids have no elastic limit.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

Liquid pressure and total force
Pressure on a confined liquid
Pressure of air
Measuring expansion caused by heat
The automobile

PRINCIPLE

34. Gases may be converted into liquids by reducing the speed of their molecules.

MAJOR TOPIC

Measuring expansion caused by heat

PRINCIPLE

35. The height to which a liquid rises in a capillary tube is directly proportional to the surface tension of the liquid and inversely proportional to the density of the liquid and to the radius of the tube.

MAJOR TOPIC

Molecular attraction

PRINCIPLE

36. In the northern hemisphere great volumes of air revolve in a counter-clockwise direction, and in the southern hemisphere, they revolve in a clockwise direction.

MAJOR TOPIC

Study of meteorology

PRINCIPLE

37. Condensation will occur when a vapor is at its saturation point if centers of condensation are available and if heat is withdrawn.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

Heat and the state of matter
Conduction

PRINCIPLE

38. The lower the temperature of a body, the less the amount of energy it radiates; the higher the temperature, the greater is the amount of energy radiated.

MAJOR TOPIC

Radiation

PRINCIPLE

39. The atmosphere of the earth tends to prevent the heat of the earth's surface from escaping, and the earth begins to cool only when the amount of heat lost during the night exceeds that gained during the day.

MAJOR TOPICS

Wind, water, and weather
Study of meteorology

PRINCIPLE

40. Heat is liberated when a gas is compressed, and is absorbed when a gas expands.

MAJOR TOPICS

Wind, water, and weather
Expansibility and compressibility of gases
Compressed air
Measuring expansion caused by heat
Heat and the state of matter
Convection
Conduction
Study of meteorology
Relation between heat and work
Utilizing heat
How the internal combustion engine works

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
41. Heat is transferred by convection in currents of gases or liquids the rate of transfer decreasing with an increase in the viscosity of the circulating fluid.
MAJOR TOPICS
Wind, water, and weather
Measuring expansion caused by heat
Heat and the state of matter
Convection
Study of meteorology
Relation between heat and work
Utilizing heat
How the internal combustion engine works
PRINCIPLE
42. The rate of vaporization decreases with an increase of concentration of the vapor in the gas in contact with the liquid, the temperature remaining constant.
MAJOR TOPICS
Heat and the state of matter
Convection
PRINCIPLE
43. Most bodies expand on heating and contract on cooling, the amount of change depending upon the change in temperature.
MAJOR TOPICS
Expansibility and compressibility of gases
Behavior of matter
Molecular attraction
Nature of heat
Change of temperature of matter
Measuring expansion caused by heat
Measurement of heat
Heat of fusion

TABLE II (CONTINUED)

Principles and Major Topics

Heat and the state of matter
Convection
Conduction

PRINCIPLE

44. The higher the temperature of the air, the greater the amount of moisture required to saturate it.

MAJOR TOPICS

Wind, water, and weather
Heat and the state of matter
Convection

PRINCIPLE

45. Movements of all bodies in the solar system are due to gravitational attraction and inertia.

MAJOR TOPICS

Wind, water, and weather
Force of gravity
Newton's laws of motion
Study of meteorology
Nature and velocity of light

PRINCIPLE

46. Energy can never be created or destroyed (except in Nuclear Physics); it can be changed from one form to another with exact equivalence.

MAJOR TOPICS

Matter and energy
Principle of conservation of energy
Aid of machines in doing work
Mechanical advantages of machines
Compound machines
Efficiency of machines
Heat of fusion
Heat and the state of matter
Relation between heat and work
Utilizing heat
How the internal combustion engine works

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
47. Solids are liquefied and liquids are vaporized by heat; the amount of heat used in this process, for a given mass and a given substance, is specific and equals that given off in the reverse process.
MAJOR TOPICS
Matter and energy Molecular attraction Heat and the state of matter Conduction Relation between heat and work Utilizing heat
PRINCIPLE
48. A fluid has a tendency to move from a region of higher pressure to one of lower pressure; the greater the difference, the faster the movement.
MAJOR TOPICS
Pressure of air Wind, water, and weather Expansibility and compressibility of gases Behavior of matter Molecular attraction The nature of a solution Heat and the state of matter Convection Conduction Radiation Study of meteorology Relation between heat and work Utilizing heat How the internal combustion engine works
PRINCIPLE
49. The principal cause of wind and weather changes is the unequal heating of different portions of the earth's surface by the sun; thus all winds are convection currents caused by unequal heating of different portions of the earth's atmosphere, and they blow from places of high atmospheric pressure.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

Wind, water, and weather
Heat and the state of matter
Study of meteorology

PRINCIPLE

50. The total mass of a quantity of matter is not altered by any chemical changes occurring among the materials composing it.

MAJOR TOPIC

Matter and energy

PRINCIPLE

51. When two bodies of different temperature are in contact, there is a continuous transference of heat energy, the rate of which is directly proportional to the difference of temperature.

MAJOR TOPICS

Nature of heat
Measurement of heat
Heat of fusion
Heat and the state of matter
Convection
Conduction
Radiation

PRINCIPLE

52. The atmospheric pressure decreases as the altitude increases.

MAJOR TOPICS

Pressure of air
Wind, water, and weather
Heat and the state of matter
Study of meteorology
The airplane and its control

TABLE II (CONTINUED)

Principles and Major Topics

PRINCIPLE

53. The presence of a dissolved substance will cause the resulting solution to boil at a higher temperature and to freeze at a lower temperature than pure water.

MAJOR TOPICS

The nature of a solution
Heat of fusion
Heat and the state of matter

PRINCIPLE

54. Freezing point depression and boiling point elevation are proportional to the concentration of the solution.

55. Every pure liquid has its own specific boiling and freezing point.

MAJOR TOPICS

Heat of fusion
Heat and the state of matter

PRINCIPLE

56. The speed of diffusion of gases varies inversely with the square root of their densities.

57. When a mixture of gases is confined, each exerts its own pressure without reference to the pressure exerted by others.

MAJOR TOPIC

Expansibility and compressibility of gases

PRINCIPLE

58. Matter may be transformed into energy and energy into matter the sum total, mass plus energy, remains constant.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS Matter and energy Principle of conservation of energy Nature of heat Radio-activity
PRINCIPLE 59. The boiling point of any solution becomes lower as the pressure is decreased and higher as the pressure is increased.
MAJOR TOPICS The nature of a solution Heat and the state of matter
PRINCIPLE 60. Heat is conducted by the transfer of kinetic energy from molecule to molecule.
MAJOR TOPICS Matter and energy Behavior of matter Nature of heat Change of temperature of matter Measuring expansion caused by heat Heat and the state of matter Convection Conduction Radiation
PRINCIPLE 61. The energy which a body possesses on account of its position or form is called potential energy and is measured by the work that was done in order to bring it into the specified condition.
MAJOR TOPIC Principle of conservation of energy

TABLE II (CONTINUED)

Principles and Major Topics

PRINCIPLE

62. The pressure in a fluid in the open is equal to the weight of the fluid above a unit area including the point at which the pressure is taken; it therefore varies as to the depth and average density of the fluid.

MAJOR TOPICS

Liquid pressure and total force
Pressure on a confined liquid

PRINCIPLE

63. If the volume of a confined body of gas is kept constant, the pressure is proportional to the absolute temperature.

64. If the same pressure is maintained, the volume of a gas is varied directly as the absolute temperature.

MAJOR TOPIC

Measuring expansion caused by heat

PRINCIPLE

65. A change in state of a substance from gas to liquid, liquid to solid, or vice versa, is usually accompanied by a change in volume.

MAJOR TOPICS

Measuring expansion caused by heat
Heat of fusion
Heat and the state of matter
Relation between heat and work

PRINCIPLE

66. The amount of heat which a constant mass of a liquid or solid acquires when its temperature rises a given amount is identical with the amount it gives off when its temperature falls by that amount.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS Measurement of heat Heat of fusion Heat and the state of matter Conduction Study of meteorology Relation between heat and work Utilizing heat
PRINCIPLE
67. The rate of evaporation of a liquid varies with temperature, area of exposed surface and saturation and circulation of the gas in contact with the fluid.
MAJOR TOPICS Molecular attraction Heat and the state of matter
PRINCIPLE
68. The volume of an ideal gas varies inversely with the pressure upon it, providing the temperature remains constant.
MAJOR TOPICS Matter and energy Pressure of air Expansibility and compressibility of gases Compressed air Behavior of matter Measuring expansion caused by heat Utilizing heat How the internal-combustion engine works
PRINCIPLE
69. The average speed of molecules increases with the temperature and pressure.
MAJOR TOPICS Wind, water, and weather

TABLE II (CONTINUED)

Principles and Major Topics

Expansibility and compressibility of gases
Compressed air
Behavior of matter
Nature of heat
Change of temperature of matter
Measuring expansion caused by heat
Measurement of heat
Heat of fusion
Heat and the state of matter

PRINCIPLE

70. The free surface of a liquid contracts to the smallest possible area due to surface tension.

MAJOR TOPIC

Molecular attraction

PRINCIPLE

71. The pressure of a saturated vapor is constant at a given temperature, and increases with an increase of temperature.

MAJOR TOPIC

Heat and the state of matter

PRINCIPLE

72. The total change in length of a metal bar is equal to its coefficient of linear expansion times the original length times the change of temperature in degrees C.

MAJOR TOPICS

Measuring expansion caused by heat
Conduction

PRINCIPLE

73. When a gas expands, heat energy is converted into mechanical energy.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS Relation between heat and work Utilizing heat How the internal-combustion engine works
PRINCIPLE
74. Musical tones are produced when a vibrating body sends out regular vibrations to the ear while only noises are produced when the vibrating body sends out irregular vibrations to the ear.
75. Sound is produced by vibrating matter and is transmitted by matter.
MAJOR TOPICS Sound and wave motion Reflection of sound Loudness and pitch Resonance and interference Music and quality Quality of sounds Musical instruments
PRINCIPLE
76. Energy is often transmitted in the form of waves.
MAJOR TOPICS Sound and wave motion Loudness and pitch Musical instruments Nature and velocity of light Photography Heating and lighting effects of electricity Radio
PRINCIPLE
77. The higher the pitch of a note, the more rapid the vibrations of the producing body.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS
Sound and wave motion Loudness and pitch Music and quality Musical instruments
PRINCIPLE
78. Sound waves or other energy impulses may set up vibrations in a body the amplitude of which is increased if the impulses are exactly timed to correspond to any one of the natural periods of vibration of the body.
MAJOR TOPICS
Resonance and interference Quality of sounds Musical instruments
PRINCIPLE
79. When energy is transmitted in waves, the medium which transmits the wave motion does not move along with the wave, but the energy does.
MAJOR TOPICS
Sound and wave motion Loudness and pitch Musical instruments Nature and velocity of light Radio
PRINCIPLE
80. When a sounding body is moving toward or away from an observer, the apparent pitch will be higher or lower, respectively, than the true pitch of the sound emitted.
MAJOR TOPICS
Sound and wave motion Loudness and pitch Music and quality

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
81. The loudness of a sound depends upon the energy of the sound waves and, if propagated in all directions, decreases inversely as the square of the distance from the source.
MAJOR TOPICS
Sound and wave motion Reflection of sound Loudness and pitch Resonance and interference
PRINCIPLE
82. Harmonious musical intervals correspond to very simple frequency ratios.
MAJOR TOPICS
Music and quality Quality of sounds Musical instruments
PRINCIPLE
83. The speed of sound increases with an increase in temperature of the medium conducting it.
84. The velocity of sound is directly proportional to the square root of the elasticity modulus and inversely proportional to the square root of the density of the transmitting medium.
MAJOR TOPIC
Sound and wave motion
PRINCIPLE
85. Sound waves are reflected in a direction such that the angle of incidence is equal to the angle of reflection.
MAJOR TOPIC
Reflection of sound

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
86. The quality of a musical tone is determined by the pitch and intensity of the different simple tones or harmonics into which it may be resolved.
MAJOR TOPICS
Loudness and pitch Music and quality Quality of sounds
PRINCIPLE
87. Two sound waves of the same or nearly the same frequency will destructively interfere with each other when the condensations of the one coincide with the rarefactions of the other provided that the directions of propagations are the same.
MAJOR TOPICS
Sound and wave motion Resonance and interference Music and quality
PRINCIPLE
88. The frequency of the vibration of a stretched string is inversely proportional to its length, diameter, and square root of its density, and directly proportional to the square root of the stretching force.
MAJOR TOPICS
Sound and wave motion Loudness and pitch Musical instruments
PRINCIPLE
89. Smooth surfaced tubes may be employed to confine the direction of sound waves and thus prevent the rapid decrease of intensity with distance from source, which would otherwise take place.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

Sound and wave motion
Loudness and pitch

PRINCIPLE

90. The velocity of a wave is equal to the product of its frequency and wave length.

MAJOR TOPICS

Sound and wave motion
Nature and velocity of light
Radio
Radio-activity

PRINCIPLE

91. The colors of objects depend upon what light rays they transmit, absorb or reflect.

MAJOR TOPICS

Nature and velocity of light
Photometry
Reflection of light waves
Optical instruments
Color of light
Principle of the spectroscope
Polarized light
The camera
Photography

PRINCIPLE

92. The darker the color of a surface, the better it absorbs light.

MAJOR TOPICS

Nature and velocity of light
Color of light
The camera
Photography

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE 93. When light rays are absorbed, some of the light energy is transformed into heat energy. MAJOR TOPICS Principle of conservation of energy Radiation Nature and velocity of light Photometry Color of light Principle of the spectroscope Polarized light
PRINCIPLE 94. Whenever an opaque object intercepts radiant energy travelling in a particular direction, a shadow is cast behind the object. MAJOR TOPICS Nature and velocity of light Photometry Optical instruments Color of light The camera Photography
PRINCIPLE 95. Light travels in straight lines in a medium of uniform optical density. 96. Parallel light rays may be converged or focused by convex lenses or concave mirrors, diverged by concave lenses or convex mirrors. MAJOR TOPICS Nature and velocity of light Reflection of light waves What is a mirror? Images of curved mirrors

TABLE II (CONTINUED)

Principles and Major Topics

Refraction of light waves
Lenses and images
Images of curved lenses
Structure of the human eye
Optical instruments
Color of light
Principle of the spectroscope
Polarized light
The camera
Photography

PRINCIPLE

97. Dark, rough or unpolished surfaces absorb or radiate energy more effectively than light, smooth or polished surfaces.

MAJOR TOPICS

Pressure of air
Nature of heat
Nature and velocity of light
Reflection of light waves

PRINCIPLE

98. When light is reflected, the angle of incidence is equal to the angle of reflection.

MAJOR TOPICS

Nature and velocity of light
Reflection of light waves
Lenses and images
Optical instruments

PRINCIPLE

99. When waves strike an object, they may either be absorbed, transmitted, or reflected.

MAJOR TOPICS

Nature of heat
Radiation

TABLE II (CONTINUED)

Principles and Major Topics
Absorbers, radiators, and reflectors of heat Sound and wave motion Reflection of sound Music and quality Nature and velocity of light Reflection of light waves What is a mirror? Images of curved mirrors Refraction of light waves Lenses and images Images of curved lenses Structure of the human eye Optical instruments Color of light Principle of the spectroscope Polarized light The camera Photography
PRINCIPLE
100. If a beam of light falls upon an irregular surface, the rays of light are scattered in all directions.
MAJOR TOPICS
Nature and velocity of light Reflection of light waves Photography
PRINCIPLE
101. The dispersion of white light into a spectrum by a prism is caused by unequal refraction of the different wave lengths of light.
MAJOR TOPICS
Optical instruments Color of light
PRINCIPLE
102. The intensity of illumination decreases as the square of the distance from a point source.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPIC
Photometry
PRINCIPLE
103. When light rays pass obliquely from a rare to a more dense medium, they are bent or refracted toward the normal and when they pass obliquely from a dense to a rarer medium, they are bent away from the normal.
MAJOR TOPICS
Refraction of light waves Lenses and images Images of curved lenses Structure of the human eye Optical instruments Principle of the spectroscope The camera
PRINCIPLE
104. In a plane mirror a line running from any point on the object to the image of that point is perpendicular to the mirror.
105. An image appears to be as far back of a plane mirror as the object is in front of the mirror and is reversed.
MAJOR TOPIC
What is a mirror?
PRINCIPLE
106. Waves travel in straight lines while passing through a homogeneous or uniform medium.
MAJOR TOPICS
Nature and velocity of light Refraction of light waves

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
107. All rays passing through the center of curvature of a mirror are reflected upon themselves.
MAJOR TOPICS
Lenses and images Images of curved lenses Optical instruments
PRINCIPLE
108. When white light passes through a substance that absorbs some waves and not others, certain bands of color are missing with the production of an absorption spectrum.
109. Every chemical element when heated to incandescence in a gaseous state has a characteristic glow and a characteristic spectrum which can be used to identify very small quantities of the element and which is related to the molecular and atomic structure of the gas.
110. Incandescent solids and liquids emit all wave lengths of light and give a continuous spectrum.
111. Luminous vapors and gases emit only certain kinds of light producing bright-line spectra.
112. When a body which emits a bright line spectrum is moving toward or away from the observer, the lines are shifted toward the short or long wave length end of the spectrum, respectively.
MAJOR TOPIC
Color of light
PRINCIPLE
113. When light is incident upon a medium in which it will travel faster and when the angle of incidence is greater than the critical angle, it is totally reflected.

TABLE II (CONTINUED)

Principles and Major Topics

114. The speed of light in any given substance bears a constant ratio to the speed of light in air.

MAJOR TOPIC

Refraction of light waves

PRINCIPLE

115. The dimensions of an image produced by a lens or a mirror are to the dimensions of the object as their respective distances from the lens or mirror are to each other.

MAJOR TOPICS

Images of curved mirrors
Images of curved lenses
Structure of the human eye
Optical instruments
The camera

PRINCIPLE

116. A beam of light may become plane polarized as a result of any circumstance which results in the suppression of one of the rectilinear components of the vibration without affecting the components at right angles to it.

MAJOR TOPIC

Polarized light

PRINCIPLE

117. When parallel light strikes a concave spherical mirror, the rays, after reflection, pass directly through the principal focus only if the area of the mirror is small compared to its radius of curvature.

MAJOR TOPICS

What is a mirror?
Images of curved mirrors

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
118. The sum of the reciprocals of the conjugate focal lengths of a lens or mirror equals the reciprocal of the principal focal length.
MAJOR TOPICS
Images of curved mirrors Lenses and images
PRINCIPLE
119. The curvature of a wave front will be changed a given amount by a lens; namely, 1/F.
MAJOR TOPIC
Lenses and images
PRINCIPLE
120. Radiant energy travels in waves along straight lines, its intensity at any distance from a point source is inversely proportional to the square of the distance from the source.
MAJOR TOPICS
Radiation Nature and velocity of light Photometry Optical instruments The camera Photography Heating and lighting effects of electricity
PRINCIPLE
121. Each element has its own characteristic X-ray spectrum.
MAJOR TOPICS
Color of light X-rays

TABLE II (CONTINUED)

Principles and Major Topics

PRINCIPLE

122. Each vibrating particle in the wave front of any wave motion may be considered as a secondary source of spherical wavelets which spread out from their sources with the velocity of the primary wave.

MAJOR TOPICS

Nature of heat
Musical instruments
Nature and velocity of light
Color of light
Radio

PRINCIPLE

123. Like electrical charges repel and unlike electrical charges attract.

MAJOR TOPICS

Nature of magnetism
Static electricity: what it is
Current electricity - Voltaic cells
Chemical effects of electricity

PRINCIPLE

124. Magnets depend for their properties upon the arrangements of the metallic ions of which they are made up.

MAJOR TOPICS

Nature of magnetism
Terrestial magnetism
Magnetic effects of electricity

PRINCIPLE

125. A magnet always has two poles and is surrounded by a field of force.

MAJOR TOPICS

Nature of magnetism

TABLE II (CONTINUED)

Principles and Major Topics
Terrestial magnetism Static electricity: what it is Magnetic effects of electricity Electrical measuring instruments Dynamos and alternators Armatures and magnetic fields The electric motor The telephone Alternating current power Current rectifiers Radio
PRINCIPLE
126. Like magnetic poles always repel each other and unlike magnetic poles always attract each other.
MAJOR TOPICS
Nature of magnetism Terrestial magnetism Static electricity: what it is Magnetic effects of electricity How a current is produced by induction Dynamos and alternators Armatures and magnetic fields The electric motor Voltage transformer and power transmission The telephone Current rectifiers
PRINCIPLE
127. All materials offer some resistance to the flow of electric current, and that part of the electrical energy used in overcoming this resistance is transformed into heat energy.
MAJOR TOPICS
Current electricity - Voltaic cells Chemical effects of electricity Heating and lighting effects of electricity Electric power and energy

TABLE II (CONTINUED)

Principles and Major Topics

PRINCIPLE

128. The electrical current flowing in a conductor is directly proportional to the potential difference and inversely proportional to the resistance.

MAJOR TOPIC

Current electricity - Voltaic cells

PRINCIPLE

129. In a series circuit the current is the same in all parts, the resistance of the whole is the sum of the resistances of the parts, and the voltage loss of the whole is the sum of the voltage losses of the parts.

130. In a parallel circuit the total current is the sum of the separate currents, the voltage loss is the same for each branch, and the total resistance is less than the resistance of any one branch.

MAJOR TOPIC

Series and parallel wiring

PRINCIPLE

131. An emf is induced in a circuit whenever there is a change in the number of the lines of magnetic force passing through the circuit.

MAJOR TOPICS

How a current is produced by induction
Dynamos and alternators
Armatures and magnetic fields
The electric motor
Electro-magnetic induction
Voltage transformer and power transmission
The telephone
Alternating current power
Current rectifiers

TABLE II (CONTINUED)

Principles and Major Topics
PRINCIPLE
132. An electric current may be produced three ways, by rubbing or friction, chemical action, and the use of a magnetic field.
MAJOR TOPICS
Static electricity: what it is Current electricity - Voltaic cells Chemical effects of electricity Heating and lighting effects of electricity How a current is produced by induction Dynamos and alternators Armatures and magnetic fields The electric motor Electro-magnetic induction Voltage transformer and power transmission The telephone Alternating current power Current rectifiers
PRINCIPLE
133. Energy in kilowatt hours is equal to the product of amperes, volts, and time (in hours) divided by one thousand.
134. Electrical power is directly proportional to the product of the potential difference and the current.
MAJOR TOPIC
Electric power and energy
PRINCIPLE
135. The magnitude of an induced e.m.f. is proportional to the rate at which the number of lines of magnetic force change and to the number of turns of wire in the coil.
136. An induced current always has such a direction that its magnetic field tends to oppose the motion by which the current was produced.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS How a current is produced by induction Dynamos and alternators Armatures and magnetic fields The electric motor Electro-magnetic induction Voltage transformer and power transmission The telephone Current rectifiers
PRINCIPLE
137. In an uncharged body there are as many protons as electrons and the charges neutralize each other while a deficiency of electrons produces a plus charge on a body and an excess of electrons produces a negative charge.
MAJOR TOPICS Nature of magnetism Static electricity: what it is
PRINCIPLE
138. Electrons are emitted from any sufficiently hot body.
MAJOR TOPICS Static electricity: what it is Magnetic effects of electricity Heating and lighting effects of electricity The electric motor The telephone Radio Construction of a standard receiving set How television has been made possible
PRINCIPLE
139. When a current-carrying wire is placed in a magnetic field, there is a force acting on the wire tending to push it at right angles to the direction of the lines of force between the magnetic poles, providing the wire is not parallel to the field.

TABLE II (CONTINUED)

Principles and Major Topics

MAJOR TOPICS

How a current is produced by induction
Dynamos and alternators
The electric motor

PRINCIPLE

140. In a transformer the ratio between voltages is the same as that between the number of turns.

MAJOR TOPIC

Voltage transformer and power transmission

PRINCIPLE

141. The resistance of a metallic conductor depends on the kind of material from which the conductor is made, varies directly with the length, inversely with the cross sectional area, and increases as the temperature increases.

MAJOR TOPICS

Current electricity - Voltaic cells
Magnetic effects of electricity
Chemical effects of electricity
Heating and lighting effects of electricity

PRINCIPLE

142. An electric current will be produced in a closed circuit including two strips of different metals if one of the junctions is heated or cooled.

MAJOR TOPICS

Current electricity - Voltaic cells
Chemical effects of electricity
Heating and lighting effects of electricity

PRINCIPLE

143. Charges on a conductor tend to stay on the surface and to be greatest on the sharp edges and points.

TABLE II (CONTINUED)

Principles and Major Topics

144. Alternating current charges a condenser twice during each cycle inducing oppositecharges on the two plates with the result that a current appears to flow through the condenser.

145. Electrostatic induction is the separation of charges on a conductor through the influence of a neighboring charge.

146. The force of attraction or repulsion between two magnetic poles varies directly as the product of the pole strengths and inversely as the square of the distance between the poles.

147. The force of attraction or repulsion between two small charged bodies varies directly as the product of the two charges and inversely as the square of the distance between the charges.

148. Condenser capacity varies directly with the area of the plates, and inversely as the thickness of the insulation between them.

149. The electrons within an atom form shells about the nucleus, each of which contains a definite number of electrons.

MAJOR TOPIC

Static electricity: what it is

PRINCIPLE

150. An electric current will be produced in a closed circuit including two strips of different metals if one of the junctions is heated or cooled.

MAJOR TOPICS

Current electricity -Voltaic cells
Chemical effects of electricity
Heating and lighting effects of electricity

TABLE II (CONTINUED)

Principles and Major Topics

PRINCIPLE

151. The amount of heat produced by an electric current is proportional to the resistance, the square of the current and the time of flow.

MAJOR TOPIC

Heating and lighting effects of electricity

PRINCIPLE

152. Electrons will always flow from one point to another along a conductor if this transfer releases energy.

MAJOR TOPICS

Static electricity: what it is
Current electricity - Voltaic cells
Chemical effects of electricity
Heating and lighting effects of electricity

PRINCIPLE

153. Pieces of iron, steel, cobalt or nickel may become magnetized by induction when placed within a magnetic field.

MAJOR TOPICS

Nature of magnetism
Terrestial magnetism
Magnetic effects of electricity
How a current is produced by induction
Dynamos and alternators
Armatures and magnetic fields
The electric motor
Electro-magnetic induction
Voltage transformer and power transmission
The telephone

PRINCIPLE

154. Electrons change energy levels emitting or absorbing energy.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPIC Static electricity: what it is
PRINCIPLE 155. Positively charged ions of metals may be deposited on the cathode, as atoms, when a direct current is sent through an electrolyte.
MAJOR TOPICS Current electricity - Voltaic cells Chemical effects of electricity
PRINCIPLE 156. An electric current will flow in the external circuit when two metals of unlike chemical activity are acted upon by a conducting solution, the more active metal being charged negatively.
MAJOR TOPICS Static electricity: what it is Current electricity - Voltaic cells Chemical effects of electricity
PRINCIPLE 157. Gases conduct electric currents only when ionized.
MAJOR TOPICS Optical instruments Static electricity: what it is Chemical effects of electricity Heating and lighting effects of electricity Radio Construction of a standard receiving set How television has been made possible
PRINCIPLE 158. Electrons have both a magnetic and an electric field.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS Static electricity: what it is Cathode rays
PRINCIPLE 159. Two electro-magnetic waves having the same frequency and amplitude and travelling in nearly the same direction will interfere, constructively or destructively, depending upon whether they are in phase or out of phase.
MAJOR TOPIC Color of light
PRINCIPLE 160. Electrolytes dissolved in water exist partially or completely as electrically charged particles called ions.
MAJOR TOPICS Current electricity: what it is Chemical effects of electricity
PRINCIPLE 161. Electro-magnetic waves may produce electrical oscillation in a condenser circuit which is so adjusted as to oscillate naturally with the same frequency as that of the incoming waves.
MAJOR TOPICS Radio Construction of a standard receiving set Radio in aviation
PRINCIPLE 162. Whenever a high frequency oscillating current produces in the field around it oscillating electric and magnetic fields, energy in the form of an electro-magnetic wave is transmitted through space.

TABLE II (CONTINUED)

Principles and Major Topics
MAJOR TOPICS
Magnetic effects of electricity
The telephone
Radio
Construction of a standard receiving set
How television has been made possible
Radio in aviation
PRINCIPLE
163. Radioactive emission involves muclear changes.
164. Radio-activity is independent of all physical conditions;; heat, cold, pressure, and chemical state.
165. Atoms may be broken down by bombarding the nucleus with highspeed particles such as protons, alpha particles, or neutrons.
MAJOR TOPIC
Radio-activity
PRINCIPLE
166. By means of high frequency generators or vacuum-tube oscillators, sustained or continuous oscillations can be produced in a condenser circuit. Their intensity is made to vary with audio-frequency currents in a transmitter circuit to produce radio waves.
MAJOR TOPICS
Radio
Construction of a standard receiving set
PRINCIPLE
167. A number of substances will emit electrons and become positively charged when illuminated by light.
MAJOR TOPIC
How television has been made possible

TABLE II (CONCLUDED)

Principles and Major Topics

PRINCIPLE

168. When a stream of high-speed electrons strikes a body, the atoms of that body emit X-rays.

MAJOR TOPIC

X-rays

PRINCIPLE

169. In a tube which contains gas at low pressure subject to an intensely electric field, cathode rays, streams of electrons, move away from the negatively charged terminal at high speed.

MAJOR TOPICS

Cathode rays
X-rays

PRINCIPLE

170. Atoms of all elements are made up of protons, neutrons, and electrons; and differences between atoms of different elements are due to the number of protons in the nucleus and to the configuration of electrons surrounding the nucleus.

MAJOR TOPICS

Static electricity: what it is
Radio-activity

PRINCIPLE

171. Atoms have great sub-atomic energy.

MAJOR TOPICS

Nature of heat
Radio-activity

Findings. Five hundred eighty assignments of 90 major subject-matter topics were defensibly made to 171 principles of physical science, and were reasonably expected to be suitable for use to develop an understanding of the principles. Each of the 171 principles was assigned to least one topic. Fifty-three principles had one topic assigned to each of them; 24 had 2 topics assigned to each; 23 had 3 topics assigned to each; and the remaining 61 principles had from 4 to 20 topics assigned to them. The average number of topics per principle was 3.39.

CHAPTER IV

SUMMARY, CONCLUSIONS, AND RECOMMENDATIONS

STATEMENT OF THE PROBLEM

The purpose of this investigation is (1) to prepare a composite topical outline of the subject-matter topics found in five high-school textbooks of physics, as a source of informational materials with which to develop understandings of principles of physical science, and (2) to assign to principles of physical science those topics which a study of might reasonably be expected to contribute to the development of an understanding of the principles.

SUMMARY OF THE TECHNIQUES EMPLOYED

A composite topical outline was formulated from five high-school textbooks of physics. The one textbook which had the largest number of subject-matter topics served as a basis for the composite outline. The subject-matter topics contained in a textbook were considered to be its chapter, center, and paragraph headings. All the topics from the other four textbooks were combined or added to the "master" outline. The final outline was re-examined to insure that the placement of

each topic in the outline was defensible. Table I is the composite topical outline. Then the 94 major topics from this composite topical outline were assigned to 171 of Wise's 272 principles of physical science. These assignments were made on the basis that a discussion of the subject matter, represented by the topics subordinate to the major topics in the outline, would reasonably be expected to contribute to the development of an understanding of the principles to which they were assigned. Table II shows the assignments of topics to principles.

SUMMARY OF THE FINDINGS

The five textbooks contained a total of 1947 separate subject-matter topics. Only 94 of these were major topics. Seventy-eight of the 94 major topics were found in all five books. The total frequency of occurrence of topics in all five books was 5986, an average of 1197.2 topics per book.

Five hundred eighty assignments of 90 major subject-matter topics were defensibly made to 171 principles of physical science. Each of the 171 principles was assigned at least one topic. The most number of topics assigned to one principle was 20. The average number of topics per principle was 3.39.

CONCLUSIONS

Any of the five textbooks had sufficient material to help in developing most of the principles. However, some of the material in any one book did not contribute to the development of an understanding of a principle. There was apparent uniformity in relation to the major subject-matter topics to be studied at the secondary high-school level. Textbooks can be used to help develop understandings of principles of physical science, provided that the content is properly treated.

RECOMMENDATIONS

There should be developed a suitable topical outline to be used in the teaching of physics in the high-school. The topics of this outline should be based on their ability to help develop understandings of principles of physical science.

More studies of this type should be undertaken. The results from many similar studies can then be combined into a "master" outline of subject-matter topics for use in the high-school teaching of physics. It is also recommended that assignments of topics to principles be combined in like manner; and that the assignment of topics to principles be ranked in a descending order of their relative values in contributing to the development of an understanding of the principle.

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